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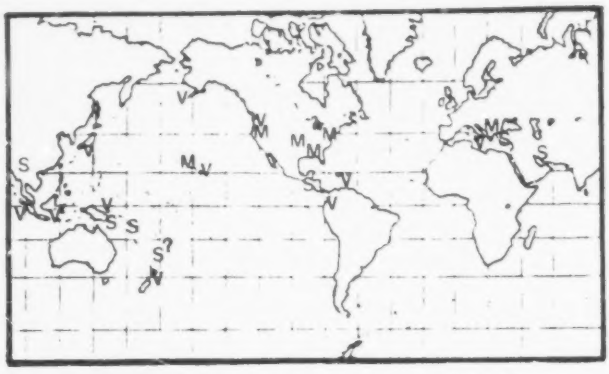

M-Meteoric S-Seismic V-Volcanic

SEAN
Scientific Event Alert Network

BULLETIN

VOLUME 11, NO.10, OCTOBER 31, 1986

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VOLCANIC EVENTS

Pavlof Volcano, Alaska Peninsula, Alaska, USA (55.42°N, 161.90°W). All times are local (GMT - 9 hours).

Airplane pilots reported that ash emissions and lava fountaining resumed in early November. Pavlof began to erupt on 16 April and there have been several episodes of strombolian activity and strong seismicity since then (see SEAN Bulletins vol. 11, nos. 3-8). No activity had been reported since mid-September. Observers named below are Reeve Aleutian Airways pilots; other reports are from the Federal Aviation Administration (FAA).

The start time of the eruption is not known, but on 30 October a clear view of the snow-covered volcano showed that it remained inactive, without vapor emissions. No other observations of Pavlof are known until 1100 on 6 November when activity was first reported. At 1130 Lee Goch and Don Munson observed a 2,750 m-high plume of dark ash and white vapor drifting more than 40 km to the NE. An incandescent lava fountain (about 10 m high) emerged from a vent just SE of the summit. Two fresh-looking, gray-black, linear, flow-like features, 120 m and 50 m wide, extended about 1/3 of the way down the SE and NW flanks. Neither feature emitted any steam, and both were free of snow. The rest of the volcano remained covered with white snow. At 2045 a pilot reported that lava fountaining was continuing at the SE summit vent.

On 10 November at 1135 James Fredenhagen and Ken Gendron observed bubbling incandescent lava and a 10 m-high, 6 m-wide fountain in a crater on the upper SE flank, about 120 m below the summit. A vertical ash and steam plume rose to about 300 m above the vent.

Fredenhagen did not see incandescent lava during a 12 November flight at 1140, but vapor and ash were released from the SE summit-area vent and drifted eastward. Earlier that day he passed through a haze layer at 1500-1800 m altitude during his approach to Sand Point, 90 km to the east. A fissure-like feature extending from the summit to at least halfway down the SE flank appeared to be emitting black ash and depositing it nearby. No incandescent material or vapor was visible in the fissure.

On 14 November Edward Livingston reported that grayish-black ash deposits covered the entire SE side of the volcano. At 1200 on 17 November a 3,600-3,900 m-high plume issued from the vent below the SE crater. Black ash pulses occurred at 5-8 minute intervals and winds blew the ash SE in a 70 km-long cloud. By the afternoon (around 1400-1630) the FAA reported that the the plume had grown to 4,500 m height.

On 18 November the FAA reported that the semi-continuous plume was 4,200 m high

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Pavlof Volcano (continued)

between 1000 and 1030. At 1512 an image from the NOAA 9 polar orbiting satellite recorded a weak plume extending 50-60 km to the N. The FAA has warned pilots in the area not to go below 3,750 m and to avoid the vicinity of the volcano.

Information contacts: John Reeder, Alaska Division of Geological and Geophysical Surveys, P.O. Box 772116, Eagle River, AK 99577 USA; Betsy Yount, Branch of Alaskan Geology, USGS, 4200 University Drive, Anchorage, AK 99508 USA.

Mt. St. Helens Volcano, Cascade Range, S Washington, USA (46.20°N, 122.18°W). All times are local (= GMT - 7 hours through 25 October; GMT - 8 hours thereafter).

In late October, Mt. St. Helens completed its second dome-building episode of 1986, about 5 months after the previous episode (see SEAN Bulletin v. 11, nos. 4 and 5). After 3 weeks of increasing precursory activity, the new lobe began to emerge from a fissure near the center of the dome during the night of 21-22 October (see last month's Bulletin).

The new lobe had added 10 m to the height of the dome by the morning of 22 October, and 20 meters more by the next day, when the dome's dimensions were estimated at 200-300 m by 200 m by 40-45 m thick. Extrusion was slow enough that wooden marker posts on top of the dome remained erect even when carried for tens of meters. Time-lapse film showed the new lava pushing upward through a N-S fissure, rising vertically, and collapsing to the sides in sheet-like masses. When geologists were next able to enter the crater, on 3 November, extrusion had ended and the dome had subsided 10 m. With earlier dome-building episodes, more typical values for post-extrusion subsidence have been 3-4 m. The new lobe appeared morphologically and petrographically similar to the May 1986 and September 1984 lobes, which were disrupted and partially buried by this extrusion episode (figures 1 and 2). Fractures 30 m deep and 30 m wide extended almost completely through the September lobe.

Thrust faults appeared on the crater floor SW of the dome for the first time since 1982 (not 1981 as reported in last month's Bulletin) disrupting debris along a 400-500 meter sector. From horizontal displacement measurements on the W side of the dome, just N of the faults, Don Swanson estimates that fault offset was 7 m. Tear faults, some showing strike-slip movement, bounded the thrust blocks.

The October dome-building episode released much more seismic energy than that of May 1986. Most earthquake magnitudes were near or slightly below 3. The high energy release seemed to result from the large number of surface events during the break-up of the oversteepened May and September lobes, and the development of thrust faults in the crater floor.

Tiltmeters recorded consistent outward co-seismic tilting on all 4 flanks of the dome. The strongest occurred on the W flank, where 11° of outward tilt was recorded before the instrument was destroyed at 0400 on 22 October. Just under 1° of tilt (15,000 microradians) was recorded on the N flank. The S and E flanks tilted outward 4500 and 4000 microradians, then several hundred microradians inward after extrusion of the lobe. The N flank did not show a similar relaxation. Total horizontal displacement along electronic distance measurement lines reached 5-10 m on the SW flank (before that target was destroyed on 22 October) and 7 m on the W flank.

SO_2 emissions peaked at 675 $\pm$ 50 tons per day (t/d) on 22 October, up from 550 $\pm$ 50 t/d on 21 October. Emission rates decreased to 260 $\pm$ 50 t/d on 23 October and 160 $\pm$ 15 t/d by 24 October.

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Mt. St. Helens Volcano (continued)

Stationary magnetometers on the dome's SE flank and base recorded no change in field intensity during the event. In the past, handheld magnetometer data had indicated that the dome magnetized at the rate of a few gammas per day after extrusion of a new lobe.

Information Contacts: Donald Swanson, Daniel Dzurisin, Elliot Endo, and Patrick Pringle, USGS Cascades Volcano Observatory, 5400 MacArthur Blvd., Vancouver, Washington 98661 USA; Chris Jonientz-Trisler, Geophysics Program, University of Washington, Seattle, Washington 98195 USA.

Figure 1: Oblique airphoto by Lyn Topinka on 28 October, looking north, showing the lava dome, the crater breach, Spirit Lake (middle distance), and Mt. Rainier (background).

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Mt. St. Helens Volcano (continued)

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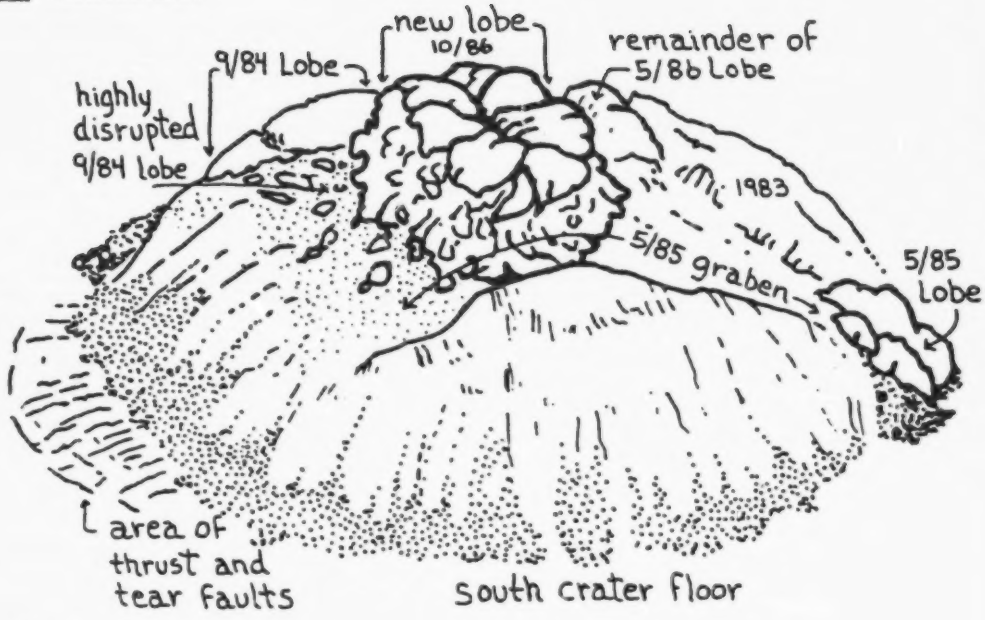

Figure 2: Drawing by Bobbie Myers of the primary features of the composite lava dome as of 28 October.

Kilauea Volcano, Hawaii USA (19.42°N, 155.27°W).

The eruption that began on 19 July at a new vent in the middle east rift zone was continuing in mid-November. The lava shield around the vent grew 2 m in height in October, to 46 m, but had not changed significantly in diameter despite occasional spillovers from the active lava pond. The level of the pond varied from 5 m below the rim to overflowing. Most flows were tube-fed to the SE. As of 3 November the longest was 6.8 km from the vent and had reached 290 m elevation, about 3.8 km from Chain of Craters Road (figure 3). The lava production was about 500,000 m³/day.

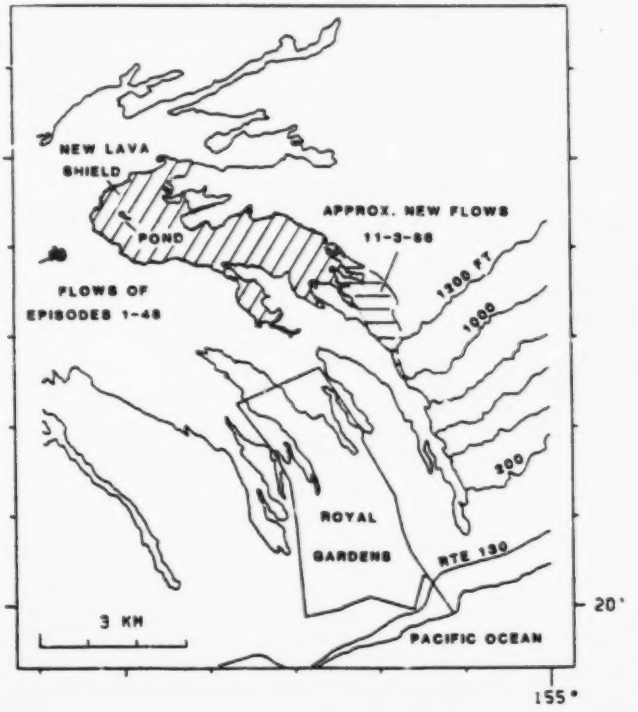

Figure 3: Sketch map of the Kilauea eruption area as of 3 November. Episode 48 lava flows emplaced through September are marked by diagonal lines; October and early November lava is shown by horizontal lines.

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Kilauea Volcano (continued)

The flows have not threatened inhabited areas, but large areas of forest have burned in the Kapaahu and Kaunaloa districts. Some residents with respiratory problems have left the Royal Gardens subdivision, especially at night when the wind direction commonly changes, bringing heavy smoke from burning vegetation upslope of the houses.

Summit tilt showed minor fluctuations (figure 4) but no significant trend of inflation or deflation. Harmonic tremor in the middle east rift zone continued at low levels with sporadic variations in amplitude.

Information contact: Christina Heliker, U.S. Geological Survey, Hawaiian Volcano Observatory, P. O. Box 51, Hawaii National Park, Hawaii 96718 USA.

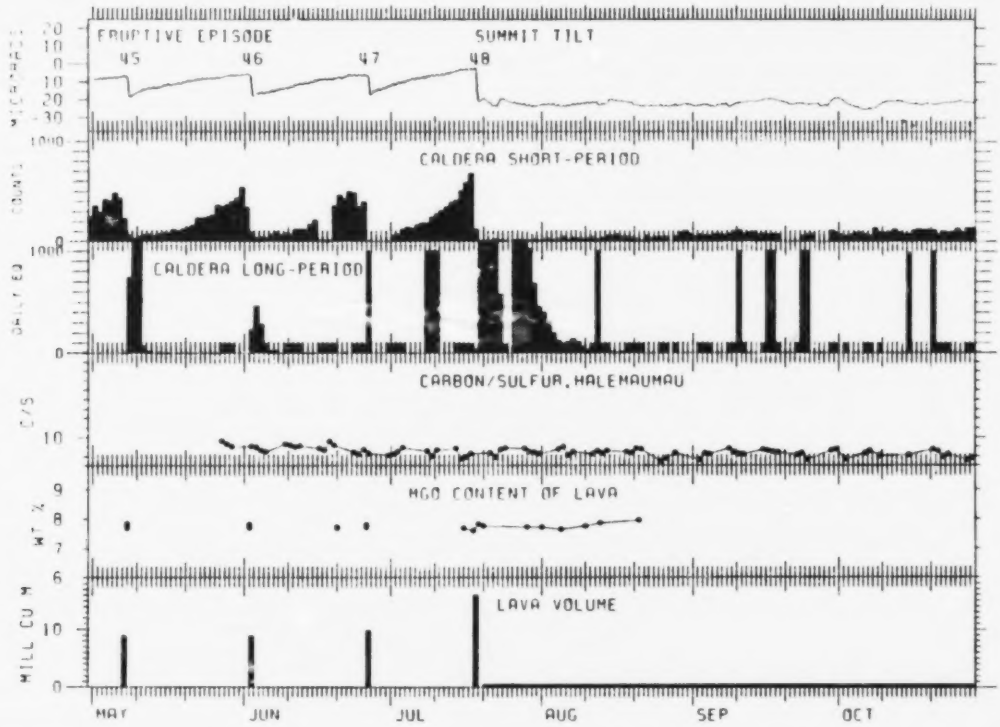

Figure 4: Six-month summary of Kilauea activity, showing tilt, short- and long-period caldera earthquakes, carbon/sulfur ratio of summit gases, lava volumes, and the MgO content of lavas produced prior to and during major eruptive episodes. A substitute tiltmeter is currently in use as indicated by the break in the summit tilt curve.

Morne Patates Volcano, Dominica, West Indies (15.22°N, 61.37°W). All times are local (= GMT - 4 hours).

Four swarms of felt earthquakes centered near Morne Patates, on the southern tip of Dominica, have occurred since March (table 1). Activity typically consisted of 10-30 recorded A-type volcanic shocks in a roughly two-hour period, about half of them felt by residents of flank villages. The most recent swarm occurred on 29 October (after 10 days of quiet) when 26 earthquakes were felt between 0000 and 0200. As of 12 November, no new swarms had been recorded.

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Morne Patates Volcano (continued)

Table 1: 1986 Earthquake Swarms at Morne Patates

Date	9-15 March	15-16 September	19 October	29 October
Number of recorded events	15	15	9	26

Three telemetered seismometers on Dominica and 15 others within 100 km recorded the events. Precise depth and magnitude determinations were difficult, but the events were shallow, perhaps at about 3 km depth, and the largest had duration magnitudes of 3-3.5. Instruments were able to detect events of about magnitude 2 or larger. Geologists visited the area in early November and installed 4 additional seismic instruments in the epicentral area; data will be telemetered to Trinidad. Fumaroles in the crater and on the N flank appeared unchanged and no other surface changes were evident.

Southern Dominica contains a cluster of six Quaternary volcanoes. The largest explosive eruption in the Lesser Antilles within the last 200,000 years originated from southern Dominica 30,000 years ago. The eruption deposited the Roseau Ash, a deep-sea pyroclastic formation that includes 25 km^3 of airfall and 30 km^3 of flow deposits (Carey and Sigurdsson, 1980). Morne Patates is the youngest volcano in Dominica, occupying a depression on the southwestern flank of a larger stratovolcano, Morne Plat Pays (Wadge, 1985). Block and ash deposits from Morne Patates have been dated at 450 $\pm$ 90 years B.P. (Roobol, Wright, and Smith, 1983). At least 10 swarms of small-magnitude earthquakes have occurred since 1765. No eruptive activity has followed any of these swarms and no systematic shallowing has been documented to indicate upward migration of magma (Wadge, 1985).

References: Carey, S.N. and Sigurdsson, H., 1980, The Roseau Ash: Deep-Sea Tephra Deposits from a Major Eruption on Dominica, Lesser Antilles Arc; Journal of Volcanology and Geothermal Research, v. 7, p. 67-86.

Roobol, M.J., Wright, J.V., Smith, A.L., 1983, Calderas or Gravity-Slide Structures in the Lesser Antilles Island Arc?; Journal of Volcanology and Geothermal Research, v. 19, p. 121-134.

Wadge, G., 1985, Morne Patates Volcano, Southern Dominica, Lesser Antilles; Geological Magazine, v. 122, p. 253-260.

Information Contacts: John Shepherd, Seismic Research Unit, University of the West Indies, St. Augustine, Trinidad; Christian Antenor-Habezac, Observatoire Volcanologique de la Soufriere, I.P.G., 97120 Le Pasnasse Saint Claude, Guadeloupe.

Ruiz Volcano, Colombia (4.88°N, 75.37°W). All times are local (= GMT - 5 hours).

The following, from the Observatorio Vulcanológico Nacional, summarizes activity 11 October - 11 November.

"A swarm of tectonic earthquakes on 28 October was the major recorded seismic activity for the report period. The swarm lasted 7.5 hours, and included more than 180 events with durations of 5 seconds or more. Maximum magnitude was 2.9. The events were centered about 3 km west of Arenas Crater and 1 km NE of Olleta Crater, at about 5 km below summit level. In comparison, the much smaller swarm that initiated the present period of higher activity on 20 April occurred SE of Arenas Crater, at a shallower depth (approximately 3 km).

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Ruiz Volcano (continued)

"Long-period seismic events were less frequent than during September. Low-frequency seismic events continued at about the same rate and most still appeared to be centered near the SE station (Regio). Since about 6 November the seismic station nearest Arenas Crater (Refugio, 2.8 km to the W) recorded an increase in shallow seismic activity.

"Harmonic tremor was the lowest of any period since 4 May. Several times the signal declined to background level for hours or days. As of early November, tremor typically lasted for a few hours, often beginning after low-frequency or shallow seismic events then slowly declining. At times, the increase or decrease in signal intensity was not simultaneous at all stations, suggesting that there was more than one tremor source.

"The highest SO_2 emission rate, 5400 tons per day, was measured on 31 October during a tremorless period. The average emission rate was about 3000 tpd. Evidence of ash emission was less than during the previous month.

"After relatively strong fluctuating changes in September, deformation was weaker and less regular. The resultant tilt vectors pointed less consistently to the summit area. Some changes in deformation measurements may have been due to the effects of heavy rainfall."

Information Contacts: Hansjurgen Meyer, Observatorio Vulcanológico Nacional, INGEOMINAS, Apartado Aereo 1296, Manizales, Colombia.

Etna Volcano, Sicily, Italy (37.73°N, 15.00°E). All times are local (GMT + 1 hour).

Following the paroxysmal explosion of 24 September (see last month's Bulletin), a new system of eruptive fissures opened at the base of the central crater on 30 October. The new eruption was marked by vigorous strombolian activity and intense seismicity. Several new lava flows emerged from the fissures.

The seismic activity observed during the first several days of October continued during the following days. Both shallow and deep earthquakes occurred, mainly on the western flank of the volcano. The deepest earthquakes were at 20 km and maximum magnitude was 3.0.

At 2345 on 29 October an intense but brief seismic swarm began that included more than 40 shocks in one hour. The strongest event (magnitude 3.7), centered on the NE flank (at Piano Provenzana) occurred at 0018 on 30 October. Only a few events were recorded during the following days.

Harmonic tremor remained at late September-early October levels until 30 October, when a brief, tenfold rise in tremor amplitudes, between 0000 and 0400, accompanied the opening of a system of eruptive fissures. The 2 km-long fissure system, oriented ENE, stretched from the base of the central crater to the Valle del Leone (from 2900 m to 2500 m above sea level, on the W flank of the Valle del Bove). Several explosive vents that formed along the upper part of the fissure system were the source of gas and vapor emission, strong ash expulsions, and occasional phreatic explosions. Weak strombolian activity occurred from the lower part of the fissure system (about 2500 m altitude) and several lobes of lava flowed away from the fissures. Eight hours after the start of the eruption, two main flows were moving SE. The southern flow had advanced about 2.5 km and reached the Valle del Bove at 1750 m altitude.

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Etna Volcano (continued)

During the early afternoon the fissure system continued to propagate downslope, creating a new eruptive fissure NW of Mt. Simone, around 2300-2200 m altitude, just behind and to the side of the N "wall" of the Valle del Bove. Violent explosive strombolian activity started immediately, as four eruptive vents formed. Lava flows from the two lower vents coalesced into a single lobe that moved SE. In the late evening, strong lava fountaining began along a few hundred meters of the central part of the fissure system (around 2600-2500 m altitude). The ash and lapilli from this activity were transported by the wind 30 km to the SW.

Similar explosive activity was continuing the next morning. Lava formed three main flows (around 2700 m altitude), that moved SE and ESE. Tremor amplitude decreased significantly, but increases were later recorded during various periods of increased eruptive vigor. Strong strombolian activity from the Southeast Crater began in the early afternoon. Isolated but violent explosions continued until the next day (1 November) when lava overflowed from the Southeast Crater and moved SE for a few hundred meters. Lava effusion from the Southeast Crater ended during the morning of 2 November and ash expulsions, sometimes violent, began.

During the first few days of November, violent explosions audible on the entire SE flank marked periods of intense ash expulsion from the new eruptive vents (particularly from those around 2300-2200 m altitude). The numerous lava flows remained above 1500 m altitude, forming a large lava field.

Strombolian activity from the bottom of the two central crater vents continued through October. From the beginning of the 30 October eruption, vapor emission of fluctuating intensity alternated with expulsions of significant amounts of dark ash from these vents. Fumarolic activity occurred along the edges of the Northeast Crater.

On 3 November a magnitude 3.5 earthquake, the strongest since 30 October, occurred at 0833 in the lower part of the Valle del Bove. As of the morning of 10 November, weak strombolian activity was occurring from six explosive vents, two around 2500 m altitude, and four around 2300-2200 m. Lava from the two eruptive systems merged and formed a single flow. It advanced 200 m past Rocca Musarra (on the north side) and penetrated farther inside the Valle del Bove than any other flow, to 1450 m. At least two large scoria cones were forming over the vents.

Information Contacts: R. Romano, G. Budetta, T. Caltabiano, D. Condarelli, and O. Consoli, Istituto Internazionale di Vulcanologia (IIV), Viale Regina Margherita 6, 95123 Catania, Italy; G. Luongo, IIV and Osservatorio Vesuviano, 80056 Ercolano, Napoli Italy; S. Gresta, Istituto di Scienze della Terra, Università di Catania, Italy.

Oshima Volcano, Izu Islands, Japan (34.73°N, 139.38°E). All times are local (= GMT + 9 hours).

An eruption from the central crater (Miharayama) began the evening of 15 November. An eruption column rose 3,200 m above the summit. Small eruptions were continuing the next day, sending ejecta to 500 m. Ash fell over an extensive area. By the morning of 19 November a 5-lobed lava flow had destroyed an observatory tower and Shinto shrine near the crater rim, and was moving down the NW flank at about 1 m per hour. By midday the flow was about 50 m long. "Lava" was ejected to 500 m above the summit and ash rose more than 1.5 km. In the mid-afternoon of 21 November, a 600 m-long fissure opened, extruded lava that flowed toward populated areas, and sent ejecta to about 1100 m height. Thousands of residents and tourists in 5 communities

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Oshima Volcano (continued)

north and west of the crater were forced to evacuate. Forty forest fires were reported and domestic flights were rerouted to avoid the volcano. Damage to crops was estimated at $1.2 million, but no casualties were reported.

United Press International reported that the Japan Meteorological Agency recorded 19 earthquakes with epicenters in the ocean, 10 km from Oshima, on the second day of the eruption. The strongest (4 on the Japanese intensity scale of 7) occurred that evening at 1846. The Associated Press reported that by 19 November more than 150 submarine events had been recorded. Seventy more recorded earthquakes that began at 1417 on 21 November preceded the fissure opening. One event registered 5 and at least two registered 4 on the Japanese intensity scale.

Since the last eruption in February-June 1974, activity has been limited to earthquake swarms, in 1977, 1983, 1985, and 1986. Volcanic tremor began 20 July 1986 and continued through September, accompanied by occasional earthquake swarms (see last two SEAN Bulletins).

Information Contacts: United Press International; Associated Press.

Submarine Explosion, Kermadec Islands, S Pacific Ocean (24.58°S, 175.52°W). All times are local (= GMT + 13 hours).

On 11 November at 0710, the yacht Nutra, traveling from Raratonga to Auckland, was shaken violently at 24.58°S, 175.52°W in what was described as an underwater explosion. Disturbed sea conditions preceded the main explosion.

The reported location is approximately 100 km E of the trend of the Tonga-Kermadec chain, over the W edge of the Tonga Trench at its S end; 570 km NNE of Raoul Island and 380 km S of Tongatapu. We are not aware of previous reports of activity in this area. The Worldwide Seismic Network recorded no nearby earthquakes at the time, although aftershocks of the magnitude 8.2 Kermadec Islands event of 20 October (see Earthquakes report, this Bulletin) continued 400 km to the south.

Information Contacts: John Latter, D.S.I.R. Geophysics Division, P.O. Box 1320, Wellington, New Zealand; National Earthquake Information Service, USGS, Stop 967, Denver Federal Center, Box 25046, Denver, Colorado 80225 USA.

Volcanic Activity in Papua New Guinea

Rabaul Caldera, New Britain Island (4.27°S, 152.20°E).

"Activity remained at a low level throughout October. There were 205 recorded small-magnitude earthquakes, compared with 298 in August and 314 in September. The daily occurrence rate varied between 0 and 18 events. Only 12 earthquakes were large enough to be located, and these were distributed in the Vulcan and Greet Harbour areas.

"Tilt and horizontal distance measurements showed insignificant inflation rates. Levelling measurements showed a maximum of 7 mm uplift at Matupit Island from August to October, and 13 mm uplift at the foot of Tavurvur Cone from July to October."

Bagana Volcano, Bougainville Island, Solomon Islands (6.14°S, 155.19°E).

"Seismicity and visual surveys indicated that the viscous extrusive phase from Bagana's summit crater continued into October at a moderate level. Emissions of

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Bagana Volcano (continued)

whitish to brown vapour were quietly released from the crater, with a weak glow at night. Reports of daily glow on the northern flank of the volcano from 21 to 29 October suggested that new lava was flowing into the active channel. Seismicity remained at 0-25 B-type events per day, the lowest rate since January."

Manam Volcano, off the N coast of New Guinea (4.10°S, 145.06°E).

"Activity remained at a low level throughout October. Weak white and white-to-brown vapours were quietly released from the main and southern craters. Seismicity rose slightly throughout the month, reaching 1000-3000 small-magnitude B-type events daily, but remained at a non-eruptive level. A deflation of 5 microradians was recorded by the Tabele water tube tiltmeter 4 km away."

Ulawun Volcano, (5.04°S, 151.34°E) and Langila Volcano, (5.53°S, 148.42°E), New Britain Island.

"Ulawun and Langila remained at non-eruptive levels of activity with emissions restricted to weak white vapour. There were no reports of incandescence or audible sounds from the summits, and seismicity was at a very low level."

Information Contacts: P. Lowenstein, Principal Government Volcanologist, and P. de Saint Ours, Rabaul Observatory, P.O. Box 386, Rabaul, Papua New Guinea.

Volcanic Activity in Indonesia

Merapi Volcano, central Java (7.54°S, 110.44°E).

Between 13 and 17 October, seismographs recorded numerous local rockfall events, at rates that reached 300-400 per day on the 15th and 16th, suggesting possible increased growth of the lava dome. No A-type or B-type shocks were detected. Seismicity declined to background after 17 October.

Geologists climbed the volcano 15 October. Heavy steaming was occurring from the lava dome, but rates of SO_2 emission had declined slightly to 70 metric tons per day, from typical rates of 100-200 tons per day. Temperatures at Woro and Gendol fumaroles remained at about 600° and 800°C.

A 2-day explosive eruption in June 1984 deposited ash 60 km to the N, generated numerous pyroclastic flows, and produced lahars that advanced down 3 river valleys (see SEAN Bulletin v. 9, no. 6). Summit lava dome growth has continued since the 1969 gas explosion.

Information Contacts: Irwan Bahar, Merapi Volcano Observatory, Volcanological Survey of Indonesia, Yogyakarta, Indonesia; Tom Casadevall, Volcanological Survey of Indonesia, Diponegoro 57, Bandung, Indonesia.

Lokon-Empung Volcano, North Sulawesi (1.36°N, 124.79°E).

Explosions from Tompaluan Crater (between Lokon and Empung cones) began in late March, emptying a small crater lake. Phreatic explosions were reported on 27 April and 2 June, became frequent in July, and continued through October. No lava flow has been observed. No juvenile material has been reported since breadcrust bombs were ejected in early September (see last month's Bulletin).

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Semeru Volcano, Java (8.11°S, 112.92°E).

Frequent vulcanian explosions continued through October from the summit crater. Semeru's eruption began in 1967.

Sangeang Api Volcano, Lesser Sunda Islands (8.18°S, 119.06°E).

Sangeang Api's eruption began 30 July 1985 with vigorous summit explosions, and lava was flowing W from the crater by early August. Lava continued to advance through at least May 1986 and glow remained visible in July (see SEAN Bulletins v. 10, nos. 7-12 and v. 11, nos. 1 and 3-7. Summit explosions decreased in September (see last month's Bulletin) but were continuing in October.

Information Contacts: Suratman and Tom Casadevall, Volcanological Survey of Indonesia, Diponegoro 57, Bandung, Indonesia.

Ruapehu Volcano, North Island, New Zealand (39.28°S, 175.57°E).

The crater lake temperature had increased to 23°C by 15 October, after cooling to 10.8°C on 31 July (see SEAN Bulletin v. 11, no. 8). Since 1980, there have been four episodes of lake cooling. Three of the cooling episodes were followed by brief periods of heating that culminated in minor hydrothermal eruptions.

Upwelling over the main vent was first observed 15 October, while upwelling over the north vent was continuous since early September. Rapid oscillations of 2-7 cm in lake level were observed on 15 October, but there were no high surges, ash deposits, or other evidence of eruptions. Sulfur emissions were at background levels and lake color has remained a battleship grey. The 15 October deformation data showed no significant changes since the July and August surveys.

Information Contact: P.M. Otway, New Zealand Geological Survey, Wairakei, New Zealand.

Atmospheric Effects

Lidar in Italy, Germany, Japan, and the USA detected the arrival of new stratospheric aerosols between 29 September and 5 November (table 2), but their source remains uncertain. The 24 September eruption of Mt. Etna produced substantial tephra falls, but ground observers estimated that the eruption column reached a maximum altitude of only 10-13 km (see last month's Bulletin). No other strong explosive eruptions have been reported in recent months.

From Fukuoka, Japan (33.65°N, 130.35°E), a sharp new peak in the lidar profile at 19.9 km altitude, accompanied by a general background increase in stratospheric aerosols, was first detected 29 September. The new peak was less distinct during the next observation, on 2 October, but the increase in total backscatter was substantial, especially at altitudes below the peak. On 6 October, a secondary peak was detected at 23 km, associated with a substantial increase in backscattering at 22-26 km. No observations were made 7-29 October, but data 30 October and 1-2 November continued to show substantially enhanced total backscatter.

Lidar in Garmisch-Partenkirchen, Germany (47.5°N, 11.0°E) showed a peak on 24 October from an apparently fresh layer that was probably not thicker than 500-1000 m. During initial observations (1807-1821 local time; = GMT + 1 hour), the peak was seen

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Atmospheric Effects (continued)

at 19.2 km altitude; later (1822-1845) at 19.8 km. Scattering ratios of the individual peaks were about 1.6. The resultant value of 1.5 for the two observation periods is used in table 2.

At Firenze, Italy (43.8°N, 11.25°E), lidar measurements resumed on 5 November, when a distinct new aerosol layer was observed from 15.5 to at least 18 km altitude. Data were noisy above 20 km, but a second peak was noted at 20.2 km and possible enhancement continued to 23 km.

At Hampton, Virginia (37.1°N, 76.3°W), a new layer at 18.5-22 km was first seen on 16 October, 1 month after the previous observation. The layer remained evident on 20 October, but by the 28th had merged with remnants of the November 1985 Ruiz aerosols. Data collected at Oshkosh, Wisconsin (44°N, 88.5°W) on 11 October did not appear to show new aerosols. Data from Mauna Loa, Hawaii (19.5°N, 155.6°W) seemed to show an increase in total backscatter, but no fresh aerosol layers were evident (figure 5).

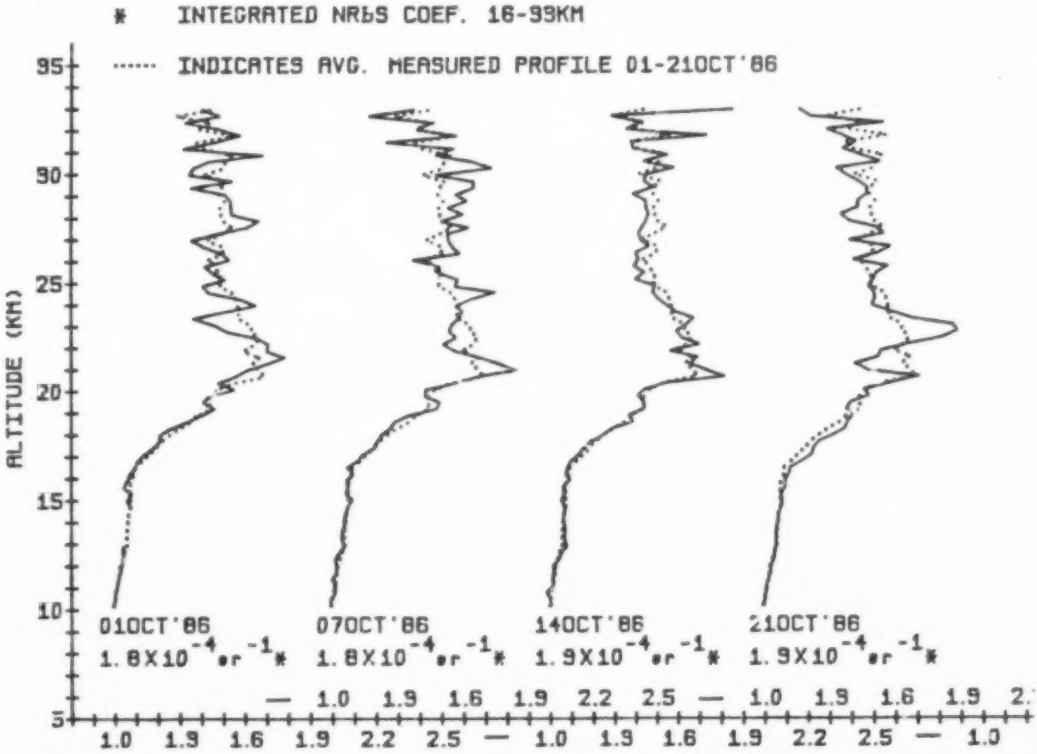

Figure 5: Lidar profiles from Mauna Loa, Hawaii 1-21 October. The dotted line superimposed on each profile represents the average October data.

Particle sampling data from balloons launched near Laramie, Wyoming (41.3°N, 105.7°W) showed a new layer of condensation nuclei (CN), too small to be detected by lidar, on 5 September. CN concentrations were about 100 times normal background values in a zone about 0.75 km thick. By 1 October, the layer had broadened to 2 km (22-24 km altitude) but concentrations had decreased to about 5 times background. In early September, particle sizes were an order of magnitude smaller than normal for that altitude, but were somewhat larger by the beginning of October. Balloon launches from Laramie will resume in December.

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Atmospheric Effects (continued)

TABLE A

LOCATION	DATE	LAYER ALTITUDE IN KM (peak in parentheses)		BACKSCATTERING COEFFICIENT	RATIO	INTEGRATED
Garmisch-Partenkirchen	14 Oct	11-?	(18.0)		1.5	
West Germany	18 Oct	10-33	(19.2)		1.4	
(47.5°N, 11.0°E)	24 Oct	10-32	(19.2)		1.5	
Oshkosh, Wisconsin	11 Oct	14-25	(18.5)		1.13	
(44°N, 88.5°W)						
Firenze, Italy	5 Nov	15.5-23	(17.6)		1.5	0.5-0.82 $\times 10^{-3}$
(43.8°N, 11.25°E)			(20.2)		1.5	
Hampton, Virginia	16 Oct	15.8-28	(20.6)		1.49	0.13 $\times 10^{-3}$
(37.1°N, 76.3°W)		24-27.5	(25.2)		1.12	
	20 Oct	12.5-28	(20.3)		1.54	0.19 $\times 10^{-3}$
		19-22	(20.3)		1.54	
	28 Oct	16.2-28	(19.5)		1.47	0.11 $\times 10^{-3}$
Fukuoka, Japan	29 Sep	17.0-22.5	(19.9)		2.64	
(33.65°N, 130.35°E)	2 Oct	14-0-22.0	(19.9)		2.83	
	6 Oct	16.5-26.5	(19.9)		2.45	
			(22.9)		1.93	
	30 Oct	16.0-23.5	(19.9)		2.75	
	1 Nov	16.0-22.5	(19.9)		3.14	
	2 Nov	14.5-22.5	(15.4)		2.37	
			(19.9)		3.44	
Mauna Loa, Hawaii	1 Oct	16-23	(21.6)	0.25×10^{-7}	1.8	0.18 $\times 10^{-3}$
(19.5°N, 155.6°W)	7 Oct	16.5-26.5	(21)	0.30×10^{-7}	1.8	0.18 $\times 10^{-3}$
			(24.6)	0.14×10^{-7}	1.8	
	14 Oct	16.5-25	(20.7)	0.31×10^{-7}	1.8	0.19 $\times 10^{-3}$
	21 Oct	16.5-24	(20.7)	0.27×10^{-7}	1.7	0.19 $\times 10^{-3}$
			(22.8)	0.23×10^{-7}	1.9	

Table 2: Lidar data from various locations, showing altitudes of aerosol layers. Note that some layers have multiple peaks. Backscattering ratios from Fukuoka, Japan are for the Nd-YAG wavelength of 1.06 microns; from Oshkosh, Wisconsin for the Nd-YAG wavelength of 0.53 microns; all others are for the ruby wavelength of 0.69 microns. An explanation of the relationship of ruby and Nd-YAG values is on p. 15-16 of SEAN Bulletin v. 9, no. 10. Integrated values show total backscatter, expressed in steradians^{-1}, integrated over 300-m intervals from 16-33 km at Mauna Loa and from the tropopause to 30 km at Hampton. Altitudes of maximum backscattering ratios and coefficients are shown for each layer at Mauna Loa.

Information Contacts: Motowo Fujiwara, Physics Department, Kyushu University, Fukuoka 812, Japan; Leopoldo Stefanutti, Istituto di Ricerca sulle onde Elettromagnetiche, CNR, Via Panciatichi 64, 50127 Firenze, Italy; H. Jager, Fraunhofer-Institut fur Atmospharische Umweltforschung, Kreuzeckbahnstrasse 19, D-8100 Garmisch-Partenkirchen, West Germany; William Fuller, NASA Langley Research Center, Hampton, Virginia 23665 USA; Thomas DeFoor, Mauna Loa Observatory, P. O. Box 275, Hilo, Hawaii 96720 USA; James Rosen, Department of Physics and Astronomy, University of Wyoming, Laramie, Wyoming 82071 USA.

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EARTHQUAKES

DATE	TIME (GMT)	MAGNITUDE	LAT.	LONG.	DEPTH OF FOCUS	REGION
7 October	2328	5.3 m_b	25.50°N	102.35°E	42 km	China
10 October	1749	5.4 M_s	13.67°N	89.20°W	8 km	El Salvador
11 October	0900	5.5 M_s	37.96°N	28.59°W	24 km	Turkey
14 October	1653	6.6 M_s	4.99°S	153.58°E	shallow	Papua New Guinea
18 October	0848	4.8 m_b	29.71°N	51.34°E	shallow	Iran
20 October	0646	8.2 M_s	28.10°S	176.43°W	shallow	Kermadec Islands
24 October	1549	6.7 M_s	10.93°S	165.16°E	shallow	Santa Cruz Islands
24 October	1624	6.5 M_s	10.98°S	165.59°E	shallow	Santa Cruz Islands

A few houses collapsed and several people were injured in the Fumin area of Yunnan province during the earthquake of 7 October.

The 10 October earthquake, centered near the SE edge of San Salvador, caused serious damage or collapse of more than 2,000 buildings and triggered at least one major landslide. Almost 1,000 people were killed, more than 8,000 were injured, and tens of thousands were left homeless. Aftershock studies have indicated a NNW-trending normal fault directly beneath the city. A 3-6 km-long break extends NW from the epicenter through the center of damaged downtown San Salvador.

In Turkey, the 11 October earthquake cracked walls and damaged chimneys in the Izmir area. It was felt in Aydin and Manisa and on the Dodecanese Islands.

There were no reports of damages from the 14 October earthquake in Papua New Guinea, but it was felt in Rabaul.

During the 18 October earthquake, a few buildings were damaged in Mamasani.

The 20 October earthquake knocked items off shelves on Raoul Island, the only inhabited island in the Kermadecs, and was felt in Wellington and Napier, New Zealand. A small tsunami was generated that measured 22 cm in Hilo, 15 cm in Kahului, 13 cm in Honolulu, and 7 cm in Kailua-Kona, Hawaii. Waves were measured at 14 cm in Papeete, Tahiti and 10 cm at Pago Pago, Samoa.

No reports have been received from the Santa Cruz Islands earthquakes on 24 October.

Information Contacts: National Earthquake Information Service, U. S. Geological Survey, Stop 967, Denver Federal Center, Box 25046, Denver, Colorado 80225 USA; Branch of Seismology, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025; Associated Press; United Press International; Agence France Presse.

FIREBALLS

Bulgaria, 13 October, 1725 GMT
(1925 local time)
Observer: Nicolai Vassilev
Location: Varna (43.3°N, 27.9°E)
1st Sighting: RA 14^h20^m, decl. 53.5°

Hawaii, USA 19 October, 1104 GMT
(0104 Hawaii Standard Time)
Observers: Several, reports combined
Location: Ewa Beach (21.33°N, 158.05°W)
1st Sighting: Zenith,

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Fireballs (continued)

Last sighting: RA 12^h40^m, decl. 51.2°
Path: Downward at 45° angle
Duration: 1-2 seconds
Apparent velocity: Medium
Magnitude: -8
Color: White/yellow
Shape: Drop-like
Trail: Luminous white, sparks, 6-8° long
Termination: 2-3 fragments, vanished above horizon
Information contact: George Mandushev, Dept. of Astronomy, University of Sofia, Sofia 1126, Bulgaria.

Last sighting: Azim. 75°, alt. 50°
Path: Straight down to ENE
Duration: 4 seconds
Apparent velocity: Medium
Magnitude: -7
Color: Yellow/green, orange to rear brightened as it moved
Shape: Oval disk, or teardrop
Termination: Broke into 3 fragments separated by 3-5°
Information contact: M. Morrow, 91-1033 Hanakahi St. Ewa Beach, Hawaii 96706.

Northeastern USA, 7 October, 0229 GMT (6 October 2229 Eastern Daylight Time)

These are additional reports of a fireball observed in Connecticut and Massachusetts last month.

Observers:	Richard Berry	Arthur Horbach
Location:	Chalfont PA (40.28°N, 75.15°W)	W New Jersey (39.83°N, 75.08°W)
Path:	Moved S to N, 35° above horizon	Moved S to N, parallel to horizon
Duration:	5-8 seconds	More than 3 seconds
Magnitude:	Bright as airplane landing lights	Much brighter than Venus
Color:	White/blue, 5-10° reddish tail	White/green
Termination:		Flared brightly, vanished above horizon

Information contacts: Richard Perry, 37 Creek Rd., Chalfont, PA 18974; Arthur Horbach, 3136 Burnt House Hill Rd., Doylestown, PA 18901.

Kansas, USA, 28 October 0125 GMT (27 October 1925 Central Standard Time)
Observer: Larry Riggs
Location: Arkansas City (37.05°N, 97.03°W)
Path: Moved S to SSW, from 35° alt., downward at 65-70° angle
Duration: 3 seconds
Apparent velocity: fast
Magnitude: Bright as full moon
Shape: Roundish, 1/3 size of moon
Color: Bright bluish white
Termination: Vanished behind trees while still bright
Sound: none heard
Information contact: Larry Riggs, 1024 N. A Street, Arkansas City, Kansas 67005.

Oklahoma, USA, 10 November 0247 GMT (9 November 2047 Central Standard Time)
Observer: Jim Taylor
Location: Oklahoma City (35.47°N, 97.55°W)
1st Sighting: 305-315°, alt. 45°
Last Sighting: 300-310°, alt. 5-10°
Duration: 3 seconds
Apparent velocity: Medium
Magnitude: Bright as 1/4 moon
Color: Silver white
Trail: Greenish, luminous, 15-20° long
Termination: Vanished above horizon
Information contact: Wayne Wyrick, Kirkpatrick Planetarium, 2100 N.E. 52nd St. Oklahoma City, OK 73111.

Oregon, USA, 4 November 0330 GMT (3 November 1930 Pacific Standard Time)
Observer: David Pinkley
Location: La Pine (43.58°N, 121.50°W)
Path: Moved S to SSW, downward from 80° to about 30° altitude

Oregon, USA, 6 November 0412 GMT (5 November 2012 Pacific Standard Time)
Observer: Bob Goodstein
Location: Bend (44.06°N, 121.33°W)
Path: N to S, directly overhead

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Fireballs (continued)

Duration: 1.5 seconds
Apparent Velocity: Medium
Magnitude: Bright as half moon
Color: White
Shape: Teardrop
Trail: Luminous white
Termination: Fragmented into 3-4 pieces, dimming as they fell, behind trees
Sounds: No sounds heard

Duration: Up to 15 seconds
Apparent velocity: Medium-slow
Magnitude: Much brighter than Venus
Color: Yellow/white
Shape: Round
Trail: No apparent trail
Termination: 8-10 fragments dropped away, vanished below horizon
Sounds: No sounds heard

Information contact: Dan Krause, Pine Mountain Observatory, Bend, Oregon 97701

Southeastern USA, 10 November, 2330 GMT (1830 Eastern Standard Time, 1730 Central Standard Time).

Many people in Alabama, Georgia, North Carolina, and Tennessee reported seeing a fireball just after dark. The following report was the best documented sighting.

Observer: Dora Palmer
Location: S of Eufala, Alabama (31.82°N, 85.17°W)
Path: Seen through a break in the clouds, moved from N to NW, altitude 30-35°, downward at shallow angle;
Duration: 2-3 seconds
Apparent velocity: Medium, seemed to accelerate toward the end
Magnitude: Bright as full moon,
Apparent size: 1/2 diameter of full moon
Color: Blue/white, turning orange near termination, appeared to be flaming
Trail: Luminous white/blue 10° long
Termination: Hidden by heavy cloud cover
Sounds: None heard

Information contact: Dora Palmer, Rt. 1 Box 351A, Eufala, Alabama 36027.

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BULLETIN

VOLUME 11, NO.11, NOVEMBER 30, 1986

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FIREBALLS
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Lindsay McClelland, Elizabeth Nielsen, Marjorie Summers, Lisa Wainger

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VOLCANIC EVENTS

Bezymianny Volcano, Kamchatka Peninsula, USSR (56.07°N, 160.72°E).

Renewed extrusion of rigid blocks onto the summit lava dome was first observed on 9 December. Lava outflow started during the night of 16-17 December, accompanied by explosions that fed pyroclastic flows about 4 km long. The eruption cloud reached 5-6 km height and extended 40-50 km to the SE. The eruption ended 17 December.

Lava dome extrusion with occasional strong explosive activity has continued since Bezymianny's major 1955-56 eruption. Vigorous explosive episodes in 1984-85 destroyed part of the dome, generating large pyroclastic flows and substantial tephra falls. Several months of lava extrusion followed the end of explosive activity in July 1985 (see SEAN Bulletin v. 11, no. 4). In late June, 1986, a viscous lava flow was extruded onto the dome's E flank and two small pyroclastic flows were generated (see SEAN Bulletin v. 11, no. 7).

Information Contacts: G. E. Bogoyavlenskaya, Institute of Volcanology, Piip Avenue 9, Petropavlovsk, Kamchatskii 683006 USSR.

Chikurachki Volcano, Paramushir Island, N Kuriles, USSR (50.33°N, 155.46°E). All times are local (= GMT + 11 hours).

Crews of two fishing boats reported that a summit eruption began on 19 November at 1730. At 1807, a 1 km-high eruption column was observed, accompanied by strong electrical discharges. Geologists reported that during the day ash explosions fed a 3 km-high eruption column and a 20 m-thick lava flow, and 3 pyroclastic flows moved down the SE flank. Satellite images showed a plume extending roughly 350 km to the ENE at 2300. The next day, meteorologists at Cape Vasiliev (25 km SE of the volcano) reported loud rumbling and a large eruption plume. Geologists reported that the plume grew to about 500 km long and that 2 lava flows descended to 560 m altitude from its 1817 m summit. Five cm of ash accumulated 18 km from the vent and ash was also reported about 30 km away.

Plumes were visible on images from the Japanese GMS satellite: 120 km long on 20 November at 0431; 300 km at 1031 and 1631; 360 km at 2231; and 400 km on 21 November at 0300 (figure 1). Maximum altitude was about 10.5-11 km, based on a minimum cloud-top temperature of -51°C. Airplane pilots reported ash between 9.5 and 11 km altitude. This prompted the issuance of an official notice to aircraft (SIGMET) on 22 November at 0100, warning of ash within an irregular area bounded by 49°N, 154°E; 48°N, 179°E; 51°N, 178°W; 54°N, 165°E; and 53°N, 153°E. On 23 November, a 5 km-high gas-ash cloud was observed by geologists. Satellite images next showed activity on

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Chikurachki Volcano (continued)

24 November at 0300, but plume emission was less vigorous. After 1800, plume activity appeared to have ended. Satellite images on 26 and 30 November revealed possible small plumes that might have indicated continuing ash eruptions. Geologists reported that after 1 December lava production and explosions ended. Preliminary ejecta volume estimates were about 0.1 km^3.

Seven eruptions of Chikurachki have been documented since December 1853, when about 1 km^3 of tephra was ejected. The volcano's most recent known activity was a small eruption in August-September 1973. A neighboring cone (Tatarinov) in the same volcano group deposited a large ash layer in the late 17th century.

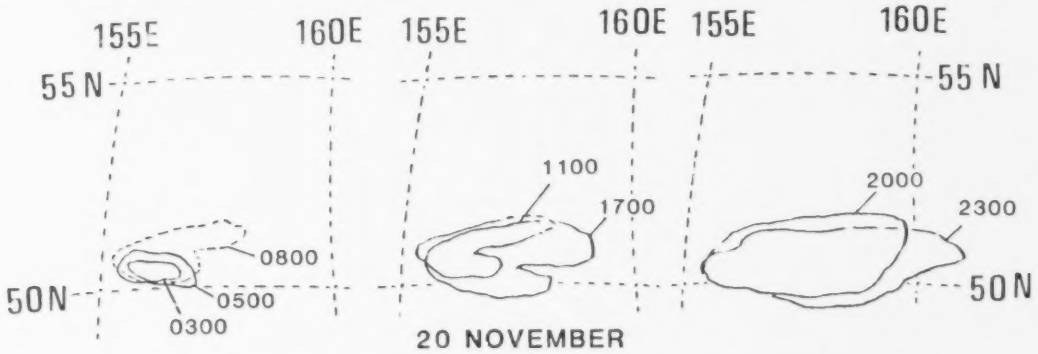

Figure 1: Eruption clouds from infrared images of the Japanese GMS satellite, courtesy of Yosihiro Sawada. Times shown are on 20 November.

Information contacts: B.V. Ivanov, G.E. Bogoyavlenskaya and A.P. Khrenov, Institute of Volcanology, Piip Avenue 9, Petropavlovsk, Kamchatskii 683006 USSR; Michael Matson, Will Gould, and Sheldon Kusselson, NOAA/NESDIS, World Weather Building, Washington, D.C. 20233; G.S. Steinberg, Box 18, Yuzhno-Sakhalinsk, 693008 USSR; Yoshiro Sawada, Japan Meteorological Agency, 1-3-4 Ote-machi, Chiyoda-ku, Tokyo 100, Japan; Sovietskaya Rossiya newspaper, Moscow, USSR; Associated Press.

Oshima Volcano, Izu Islands, Japan (34.73°N, 139.38°E). All times are local (= GMT + 9 hours).

ERUPTIVE ACTIVITY

Phase I (15-19 November)

A vigorous eruption began at 1718 on 15 November (see last month's Bulletin). The first phase, lasting 4 days, produced almost continuous lava fountains up to 500 m high (200-300 m average) and a lava lake within the crater of the 1777 cinder cone (Mihara-yama; vent A in figure 2). About 14×10^6 metric tons of scoria fell SE of vent A on 16 November and 1×10^6 metric tons SW of the vent the next day. The lava lake overflowed the crater rim at 0955 on 19 November, sending a flow 0.6 km NW before phase 1 ended at 2320. A total of 1.3×10^6 m^3 (33×10^6 metric tons) of lava were erupted at a rate of 1.3×10^6 m^3 per hour during the first phase.

Phase II (21-24 November)

After less than 2 days of quiet, the second phase began at 1615 on 21 November. A fissure opened 1.2 km NNW of the crater, on the caldera floor (B on figure 2) and

Oshima Volcano (continued)

produced lava fountains, flows, and a 9-10 km-high eruption cloud. Flows moved mostly NE and were about 1 km long by 2000. An en echelon fissure opened a few tens of meters from B at 1627. Scoria all from vent B extended east and had a maximum thickness of more than 20 cm, 3.5 km from the vent (figure 2). The first eruptive activity outside the 3 x 4 km caldera began at 1746, from a 1.5 km-long fissure (C) NW of the caldera rim. Lava fountains and flows emerged, feeding a 1.5 km-long flow that soon advanced to within 1 km of Motomachi, the island's main town, on the W coast. At 2100 lava fountaining declined; two hours later ashfall reached the Boso Peninsula, 50 km NE. Eruptive activity weakened by dawn, and by 0600 ashfall had declined. Total phase 2 ashfall was 500,000 m^3. The mass evacuation of Oshima's 10,200 residents and 2,000 tourists the night of 21-22 November was the largest operation of its kind during a natural disaster in Japan; it was completed in less than 12 hours using 39 vessels.

At 0700 on 22 November, lava production began from vent A' on the NE flank of the 1777 cinder cone; lava flowed less than 1 km to the NE. On 23 November at 1330, lava began to emerge from the south part of fissure B, advancing about 0.5 km to the NE. By 1800, steam from vents A and A' was the only evidence of eruptive activity. By 25 November the volcano was quiet.

By 24 November a 3 km-long fissure had formed on the SE part of the island (near Habu port), oriented in the same NW-SE direction as the other newly formed fissures, but no eruptve activity was observed. The lava flow that threatened Motomachi had stopped 200 m from the town as of 25 November. An occasional column of steam to about 30 m above the summit was reported on 28 November.

Eruptive activity resumed at 0547 on 18 December with a 2-hour episode that produced 800 m-high ash columns, lava fountains, and at least one series of explosions. Fifty of the 800 residents that had returned to the island gathered at a local high school. The remainder of the residents, who were still at 34 school gyms and other facilities in central Tokyo, had been scheduled to return 19 December.

The total volume of November lava was about 18 x 10^6 m^3, and scoria and ash volume was 1.9 x 10^6 m^3. Preliminary petrologic data indicated that scoria from phase 1 contained about 53% silica. Samples of scoria, lava flows, and bombs from phase 2 contain about 54-57% silica. One sample of pumice collected from the east side of the island contains about 61% silica.

Oshima has had 41 recorded eruptions since the late 18th century, most recently in 1974. The predominantly basaltic volcano typically produces small lava fountains and flows, but larger eruptions with voluminous lava and large explosions have occurred about every 100-200 years in historic time, most recently in 1684-1690 and 1777-1792.

SEISMICITY

From January to the beginning of October, seismic activity was mainly distributed in the northern and western parts of the island, generally at levels of less than 40 recorded events (M<3) per day with occasional peaks of more than 100 events per day (see SEAN Bulletins vol. 11, nos. 8 & 9). Seismicity dropped to very low levels in October, and continued at low levels until 15 November.

Seismicity rapidly increased just after noon on 16 November, 19 hours after the eruption began and reached a peak at 1846 the same day. The number of recorded

Oshima Volcano (continued)

events per hour fluctuated between 0 and 13, totalling 48 on 17 November, 40 on the 18th, and 9 on the 19th, dropping to near 0 after 0900. The largest events in phase 1 had magnitudes of 3.9 (at 1846 on 16 November) and 4.1 (at 1455 on 18 November). Epicenters of phase 1 events were in two broad zones roughly 4-7 km wide that extended N and W of the summit caldera (fig. 3). Most events were located closer to the coast than to the summit caldera.

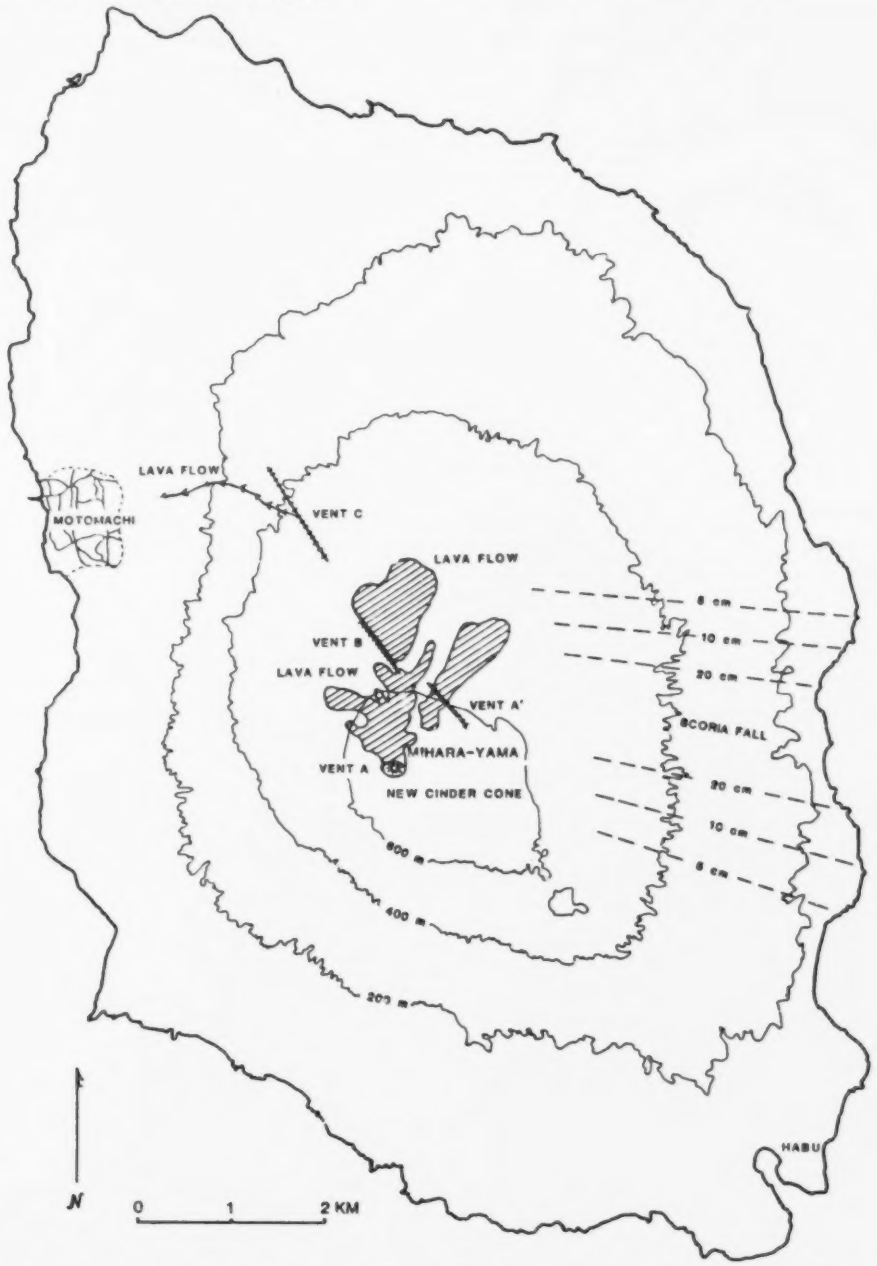

Figure 2: Sketch map showing the new cinder cone, vents, lava flows, and scoria fall. Contour interval is 200 meters. Figure courtesy of the Earthquake Research Institute.

Oshima Volcano (continued)

Seismicity increased just after 1400 on 21 November, about two hours before the start of phase 2. The number of recorded events peaked at the same time as the onset of phase 2, when about 80 events per hour, including 7 events with magnitude greater than 4, were recorded. Seismicity dropped sharply to near zero within a few days after the conclusion of the eruption on 23 Novemeber.

Phase 2 epicenters on 22 November (following the most active part of the eruption) were primarily in a NW-SE-trending zone (figure 3), roughly 3 km wide, centered about 1.5 km NE of the rift zone where phase 2 eruptions occurred. Early phase 2 epicenters have not yet been located because of crowded seismic records. Shallow events (< 5 km) were concentrated near the vents at the summit of the island, while deeper events (> 5 km) were concentrated near the NW and SE coasts and offshore.

Epicenters on 1-9 December were concentrated along the same zone as those of phase 2 (figure 3). The events were centered close to the coastline, with shallow events occurring close to the SE coast.

Episodic tremor began on 7 July, over 18 weeks before the eruption began. Pulses lasted for 10 to 20 minutes at regular intervals of approximately 3 hours until 20 July. Tremor amplitude increased several times during the months before the eruption. The pattern became more irregular at about the beginning of October, then tremor suddenly stopped on 27 October. Continuous tremor started several days later.

A higher amplitude episodic tremor was superimposed on the continuous tremor every 1-2 hours beginning on the morning of 15 November. At the onset of phase 1 that afternoon, tremor amplitude increased significantly and the characteristic period became significantly longer. Tremor stopped as phase 1 ended on 19 November at 2320.

Episodic tremor resumed the evening of 20 November. At about noon on 21 November, tremor became continuous, then stopped about 1-2 hours before the onset of phase 2 at 1615. During phase 2, tremor was not distinguished; it may have been masked by the high seismicity.

GROUND DEFORMATION

Prior to the eruption levelling surveys had been conducted at 3-10-year intervals along the two roads leading to the summit (the 1777 scoria cone). The points near the caldera were remeasured on an annual basis. Results indicate that the summit was deflating before the eruption, with about 40 mm of displacement measured from 1983 to 1986 near the center of the summit cone. Between April 1984 and August 1986, electronic distance measurements across the caldera showed contraction, consistent with deflation.

Before the eruption, a continuously recording tiltmeter near the SE end of the island showed a tilt direction consistent with deflation of the summit region. Tilt accelerated at the start of phase 1. Between phases 1 and 2, tilt was approximately constant. At the beginning of phase 2, however, tilt quickly reversed, gradually became flat, and then returned to the original direction of movement by about noon on 22 November.

Data from a continuously recording volumetric strainmeter on the NW part of the island indicated that contraction started about July 1981 and continued until the eruption. Contraction accelerated with phase 1 (consistent with the direction and trend of

Oshima Volcano (continued)

the tiltmeter on the SE part of the island) then became flat. When phase 1 ended, expansion began then sharply accelerated 2 hours before the beginning of phase 2.

The data indicated that expansion continued for nearly all of phase 2 and ended about 2000 on 21 November, after which a gradual contraction was recorded. Expansion similar to that seen on the Oshima strainmeter, but 2 orders of magnitude smaller, was seen seen on strainmeters on the Izu Peninsula on the main Japanese island of Honshu; this expansion continued for a few days after the eruption at a lesser rate.

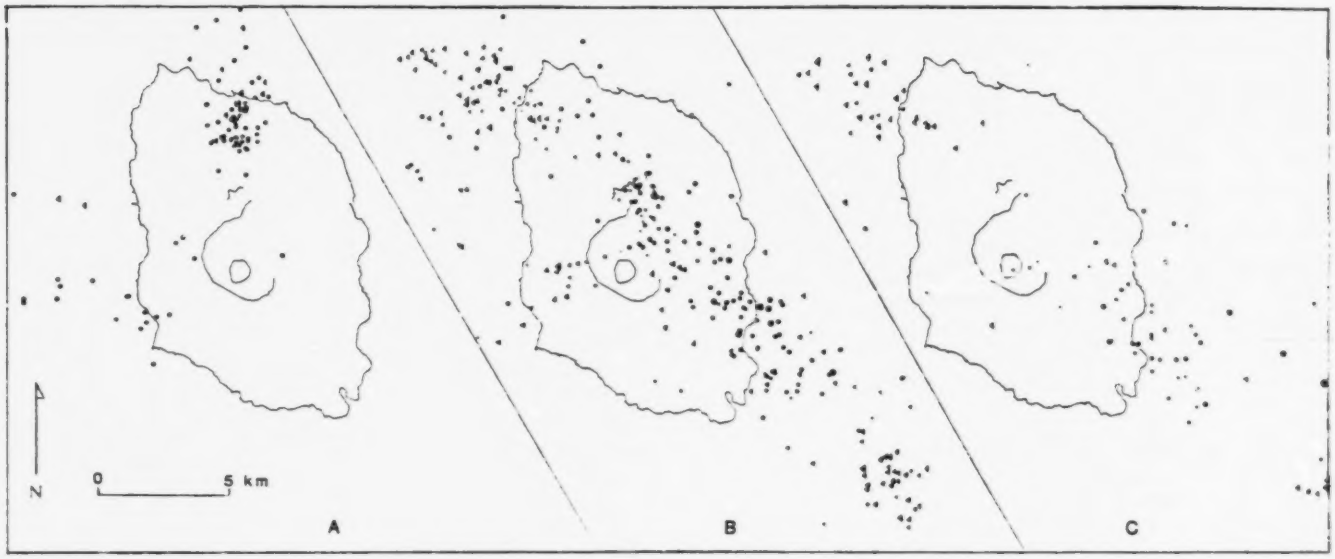

Figure 3: Plots of earthquake epicenters, courtesy of the Earthquake Research Institute: a) 1725, 15 November - 1200, 21 November; b) 0000, 22 November - 1415, 28 November; c) 0000, 1 December - 0320, 7 December.

Information Contacts: Yukio Hayakawa, Shigeo Aramaki, Yoshiaki Ida, Hidefumi Watanabe, Koshun Yamoaka, and Harry Glicken, Earthquake Research Institute, University of Tokyo, Bunkyo-ku, Tokyo 113, Japan; Yosihiro Sawada, Japan Meteorological Agency, 1-3-4 Ote-machi, Chiyoda-ku, Tokyo 100, Japan.

Sakurajima Volcano, Kyushu, Japan (31.58°N, 130.67°E). All times are local (= GMT + 9 hours).

At 1602 on 23 November, the 206th explosion recorded this year ejected a 2.5 m-diameter block onto a one-story concrete building at the foot of the volcano, 3 km south of the crater. Six people in the building were injured as the block, estimated to weigh 5 metric tons, broke through the roof and ground floor of the hotel and landed in the basement. Two other large blocks (1-1.5 m diameter) that landed near the hotel created a depression and started a grass fire. On 27 November at 0532, 300-m eruption columns were emitted. Observers heard a loud explosion and saw blocks being ejected. Twelve explosions were recorded in November and total ash accumulation was 52 g/m², 10 km W of the summit at the Kagoshima Meteorological Observatory.

During October, 21 explosions were recorded (table 1) and earthquake swarms occurred on 9 days. The ash cloud reached its maximum height of 2000 m above the crater on 11, 12 and 30 October. At 1150 on 30 October a large amount of lapilli was

Sakurajima Volcano (continued)

ejected, damaging 3 car windshields. A total of 25 g/m² of ash accumulated at the Observatory, a decrease from 171 g/m² in September.

TABLE 1

DATE: October	3	4	11	12	15	16	17	19	20	21	22	24	25	26	29	30	total
EXPLOSIONS:	1	1	1	2	1	3	1	1	1	1	2	2	1	1	1	1	21
DATE: November	2	7	14	18	21	22	23	27	28	29							total
EXPLOSIONS:	1	1	1	1	2	1	1	1	2	1							12

Information Contacts: Volcanological Center, Japan Meteorological Agency, 1-3-4 Ote-machi, Chiyoda-ku, Tokyo 100, Japan; NHK Television Network, Tokyo, Japan; The Daily Yomiuri newspaper, Tokyo, Japan; Kyodo News Agency, Tokyo, Japan; United Press International.

Suwanosejima Volcano, Ryukyu Islands, Japan (29.53°N, 129.72°E). All times are local (= GMT + 9 hours).

On 2 October observers aboard a Nihon Kinkyori Airways plane saw the volcano emitting a white plume to about 500-600 m height. An ash plume was sometimes seen from 30 km NE of the summit (in Nakanoshima) by the Japan Meteorological Agency Mobile Volcanological Observation Team.

Information Contact: Volcanological Center, Seismological and Volcanological Department, Japan Meteorological Agency, 1-3-4 Ote-machi, Chiyoda-ku, Tokyo 100, Japan.

Kilauea Volcano, Hawaii USA (19.42°N, 155.27°W). All times are local (= GMT - 10 hours).

The lava production that began in July at Kilauea's new shield vent has continued at about the same rate as the previous four months. The height of the new pahoehoe shield remained at about 46 m, while lava spillovers have increased its diameter to more than 1.6 km. An active lava pond remained on top, producing overflows beyond the shield margins, mostly to the E and SE, during early November. The lava pond was about 200 m by 100 m, elongated toward the SE, with a narrow neck that roofed over to form the main tube of the complex flow system. The level in the lava pond fluctuated between periodic overflows to as much as 10 m below the rim. Magma output was estimated to be 600,000 to 700,000 m³ per day.

Flows extended eastward, surrounding Kalalua (a prehistoric cinder cone), to Puu Kiai, formed by the September-October 1977 eruption (see SEAN Bulletin v. 2, nos. 9-10) and to the SE against the margin of the 1977 flows. By 20 November, a narrow flow had moved SSE to about 270 m elevation, advancing at a rate of 200-300 m per hour on the steeper slope. By a process of extending the tube network and widening, lava moved to about 60 m elevation late 23 November, threatening several houses at Kapaahu (figure 4). On 25 November at 2350, the 20-30 m-wide flow reached the coast (Kalapana) highway. A second lobe of the flow was further west, near the April 1984 flow, and a third lobe later bypassed a popular fresh water natural pool (Queen's Bath) used for swimming. The lava flowed west along the highway, slowing and spreading laterally for a few hours, then crossed it and destroyed nine houses the next morning. Several more were threatened. All residents of the community had been evacuated. Lava moved slowly over the gradual slope S of the highway and entered the ocean, 12 km from the vent, on 28 November (figure 4). By the next day, lava had

Kilauea Volcano (continued)

covered about 200 m of shoreline and extended 30 m into the sea. Several small lobes broke away from the main flow on 30 November, threatening 4 more houses.

On 3 December most of the lava produced at the vent was entering the ocean, but in the next 2 days decreasing amounts of lava reached the ocean because of blockages within the tube system. The lava pond was filled and overflowing on 5-6 December, then blockage cleared or was bypassed by lava breaking out and overriding earlier flows. New lobes consumed 2 more houses on 7-8 December. Pond spillovers caused short flows to the NE and SE. A total exceeding .08 km² of new land had been added to the island as of 19 December.

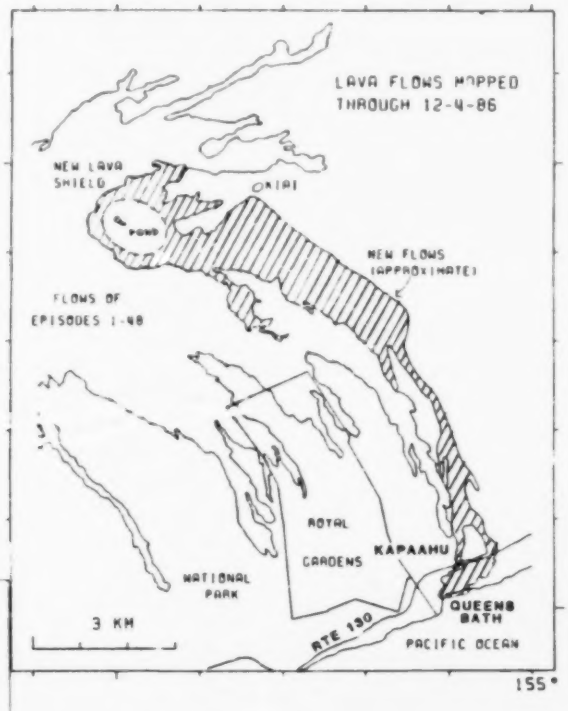

Figure 4: Sketch map of the Kilauea eruptive area as of 4 December. Lava erupted from the new shield since 20 July is shown by diagonal lines.

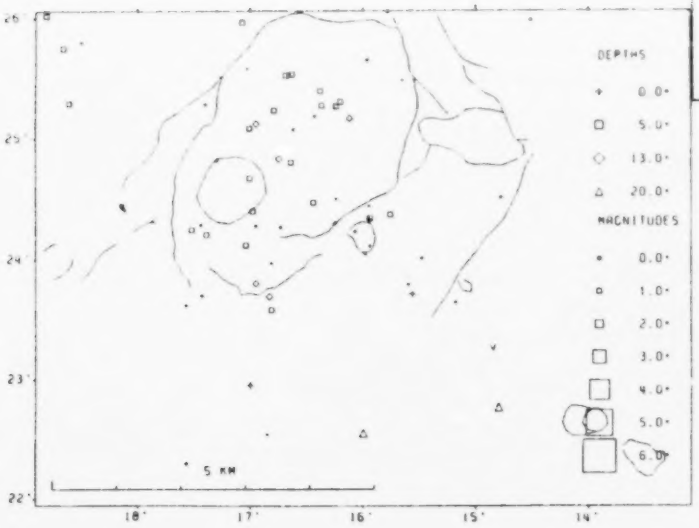

Figure 5: Map of Kilauea caldera area showing the locations of the intermediate-depth low-frequency swarm and other earthquakes occurring during November. About 20 of these events that were recorded with relatively sharp seismic signals on more than 10 stations were recorded with standard errors of about 1 km or less.

Kilauea Volcano (continued)

Low-level harmonic tremor persisted near the eruptive area along the east rift zone. Microearthquakes in the summit region continued to gradually increase. At mid-month a moderate burst of intermediate-depth low-frequency (long-period) earthquakes occurred about 5-15 km below the summit (figure 5). More than 700 events were recorded with magnitudes ranging from 0.1 to 2.0 and are associated with harmonic tremor and magma movement. Activity peaked 17-20 November, then declined.

Summit tilt, measured by EDM instruments and other tiltmeters around the caldera was unchanged. Electronic tiltmeters were affected by heavy rains throughout the month and no new data were available on the 6-month plot (figure 6).

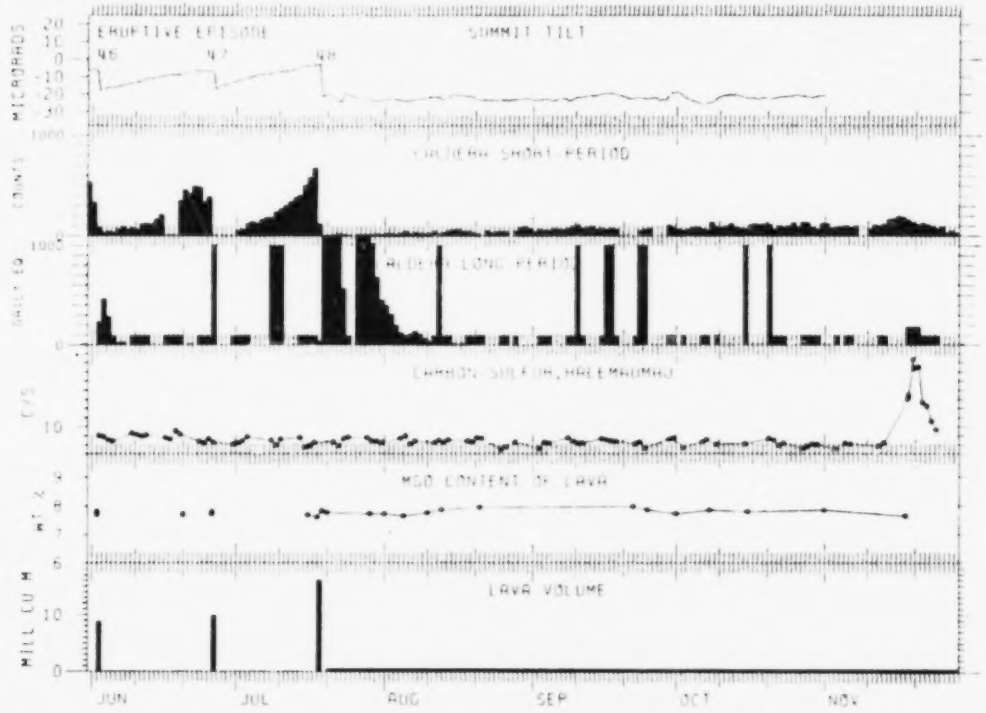

Figure 6: Six-month summary of Kilauea activity, showing tilt, short-and long-period caldera earthquakes, carbon/sulfur ratio of summit gases, lava volumes, and the MgO content of lavas produced prior to and during major eruptive episodes. The intermediate depth swarm of 17-20 November are "C" type long-period (deeper) earthquakes and the caldera long-period earthquakes are "A" type (shallow) events, so the swarm is not shown on this summary.

Information contacts: Christina Heliker and Robert Koyanagi, U.S. Geological Survey, Hawaiian Volcano Observatory, P. O. Box 51, Hawaii National Park, HI 96718 USA.

Volcanic Activity in Indonesia

Merapi Volcano, Java (7.54°S, 110.44°E).

Renewed growth of the summit lava dome began in early October and continued into November. As of mid-November, the lava dome volume was 3 x 10^6 m^3. Several hundred rockfalls per day have been occurring since mid-October.

Lokon-Empung Volcano, N Sulawesi (1.36°N, 124.79°E). All times are local (= GMT + 8 hours).

Approximately 100 explosions occurred at Tompaluan Crater in November, with about 20 recorded 21-27 November, and 33 the previous week. The strongest, on 22 November at 1921, ejected lava fragments and incandescent bombs that fell within 400 m of the crater in the south summit area. An ash column rose 1000 m and ashfall occurred over a wide area to the SE. Less than 0.5 mm of ash fell at the Kakaskasen Volcano Observatory, about 5.5 km SE of the crater. No casualties or crop damages were reported. The Observatory recorded 37 volcanic earthquakes during November.

Explosions from Tompaluan Crater, between Lokon and Empung cones, began in late March, emptying a small crater lake. Intermittent explosions have continued since then, and have been frequent since July.

Sangeang Api Volcano, Lesser Sunda Islands (8.18°S, 119.06°E). All times are local (= GMT + 8 hours).

During November more than 130 explosions were recorded from Dori Api crater. The maximum height of eruption columns was 700 m. Continued extrusion of lava was suspected but not confirmed. No volcanic earthquakes were recorded. Vigorous summit explosions began 30 July 1985 and lava was flowing W by early August. Lava was still advancing in May 1986 and glow was reported in July.

Iliboleng Volcano, Lesser Sunda Islands (8.34°S, 123.26°E). All times are local (= GMT + 8 hours).

The first explosions since 28 May occurred 10, 15, and 24 November. A gas and ash column emitted on 24 November at 0712 reached 1000 m height and was blown NNW, covering 18.7 km² with about 1 mm of ash. There were no casualties. Shallow volcanic seismicity began 30 October, with as many as 60 events per day. Eruption tremor was recorded for 1.5 minutes on 10 November.

Information Contacts: Volcanological Survey of Indonesia, Diponegoro 57, Bandung, Indonesia; Antara News Agency, Jakarta, Indonesia.

Volcanic Activity in Papua New Guinea

Rabaul Caldera, New Britain Island (4.27°S, 152.20°E).

"A small swarm of volcanic earthquakes was recorded from the Blanche Bay area on 25 and 26 November. A total of 112 and 31 events occurred on the two days. A magnitude 3.1 earthquake, the strongest recorded since May 1985, occurred under Blanche Bay near Sulphur Point. No significant ground deformation accompanied the seismic activity. Other than the increases on 25 and 26 November, seismicity remained at a low level; 316 earthquakes were recorded in November as opposed to 205 in October. The number of events per day varied from 1-22."

Ulawun Volcano, New Britain Island (5.04°S, 151.34°E).

"Activity remained at non-eruptive levels throughout November. Seismicity was at a very low level and dry tiltmeters recorded no significant tilt between 18 and 21 November. The only reported activity was weak vapour emission from the summit."

Langila Volcano, New Britain Island (5.53°S, 148.42°E).

"Steam and occasional gray-brown, low-density ash clouds were emitted throughout November. Light, fine ash fell 10 km N of the vent on 14 and 22 November. Seismicity was at a very low level."

Manam Volcano, off the N coast of New Guinea (4.10°S, 145.06°E).

"Both summit craters were at low eruptive levels throughout November. The southern crater emitted steam until 11 November, and grey-brown, low-density ash clouds from 12 November to the end of the month. The main crater emitted mostly gray-brown, low-density ash clouds with some periods of steaming. Weak sounds from the southern crater were heard on 19 and 20 November and fine ash fell on the SE side of the island. No incandescence was seen.

"Seismicity did not change significantly during the month, with 1200-1300 B-type small-magnitude events recorded per day. About 1.5 microradians of inflationary tilt were recorded 4 km away."

Bagana Volcano, Bougainville Island (6.14°S, 155.19°E).

"Seismicity and a bright glow at night from the summit indicated that lava extrusion continued at a low to moderate rate throughout November. Moderate amounts of white to brown vapour were quietly emitted."

Information Contacts: Ben Talai and Peter Lowenstein, Rabaul Observatory, P.O. Box 386, Rabaul, Papua New Guinea.

White Island Volcano, Bay of Plenty, New Zealand (37.52°S, 177.18°E).

Geologists visited the crater 29-30 October. Ash emission, predominantly from Congress Vent (active since February) on the E side of 1978 Crater, was heavy on 29 October but light the next day. The vent appeared to be inclined 40°-50° toward the base of Donald Mound, several tens of meters to the east. A level survey showed that an area NW of Donald Mound had continued to subside, a pattern that has persisted since 1984 (see SEAN Bulletin v. 11, no. 8).

Fumarole temperatures, measured in 3 vents on 29 October, ranged from 279° to 470°, continuing a general decline since 6 May. During the evening, orange glow was visible in 2 fumaroles and a blue flame (caused by sulfur oxidation) in one. No glow was observed in Congress Vent.

Two layers of gray ash had accumulated on the western portion of the main crater since 1 August; 27 mm were measured at one site east of the 1978 Crater rim. The ash, much of which was thought to be reworked crater floor tephra, resembled the July ejecta but contained less fresh magma.

Since late October 1985, low-frequency (B-type) volcanic earthquakes have dominated seismicity, occurring at a rate of 5 to more than 50 events a day. High-frequency events were relatively rare (usually fewer than 3 a day) but reached a maximum of 36 a day. Wide-band, long-duration earthquake sequences were recorded on 3 days in August and September; weak-medium amplitude, low-medium frequency volcanic tremor was recorded on 17 days in August and 9 days in October. Seismic signatures could not be correlated with any of the numerous reported eruption columns in early October.

White Island Volcano (continued)

Information Contacts: J. W. Cole, Dept. of Geology, Victoria University of Wellington, Private Bag, Wellington, New Zealand; P. Otway, and S. Sherburn, New Zealand Geological Survey (NZGS), Wairakei, New Zealand; B. J. Scott, NZGS, P.O. Box 499, Rotorua, New Zealand; W. Giggenbach, Dept. of Scientific and Industrial Research, Private Bag, Petone, New Zealand.

Submarine Explosion, Kermadec Islands, S Pacific Ocean (24.43°S, 175.50°W). All times are local (= GMT + 13 hours).

The 11 November submarine explosion reported in last month's Bulletin is now believed to have been an earthquake. To persons on board the yacht Nutra, the event sounded like a dynamite blast followed by a pair of echoes with a total duration of 1 second. Intensities of the blast and echoes were estimated by crewmen at 100, 90, and 80 decibels. No pumice, ash, or water discoloration were observed.

P and S waves, apparently from this event, were recorded at Rarotonga, Cook Islands, and Mangahao, New Zealand; local magnitude was about 4.5-5. The yacht's position at the time of the event (note revised location above), over the W side of the Tonga Trench, was determined by satellite navigation, accurate to within about 1.5 km.

Information Contacts: John Latter, DSIR Geophysics Division, P. O. Box 1320, Wellington, New Zealand; Philippa Black, Geology Department, University of Auckland, Private Bag, Auckland, New Zealand.

Piton de la Fournaise Volcano, Réunion Island, Indian Ocean (21.23°S, 55.71°E). All times are local (= GMT + 4 hours).

Ash and small quantities of lava were emitted from summit area vents in November and early December. Eruptive episodes were preceded by shallow fracturing from 18 September to about mid-November in the NE part of Dolomieu cone (figure 7). Fracturing was indicated by weak seismicity detected only by summit stations. Tiltmeters recorded a slow, minor deflation. In early November, fracturing increased and was centered 700 m under the middle of Dolomieu. Geodetic measurements indicated that the E part of Dolomieu was sliding down to the ENE, accompanied by opening of the crater's northern part. On 12 November, a very short, intense, seismic crisis (from 1150-1248) was followed by continuous tremor and a day-long ash eruption in the 29 March pit crater (see SEAN Bulletin v. 11, no. 3). The crater floor rose nearly 40 m as 30,000-40,000 m³ of ash were emitted. Seismic instruments indicated that shallow fracturing continued after the eruption. Weak seismicity continued until 17 November.

Tremor in the S part of the (Enclos) caldera began on 15 November and lasted for almost two days. Beginning on 17 November, depth, frequency, and magnitudes of seismic events increased. Magnitudes were greater than 1.0 and hypocenters were at 1500 m depth beneath the eastern part of Dolomieu Crater.

From 19-20 November a shallow seismic crisis shook the summit area and for the next six days 10-12 events per day were recorded. During the night of 25-26 November, magnitude 2.0-2.5 events occurred about 3500 m below Dolomieu Crater. The next evening (1530-1604), after 12 hours without seismicity or significant deformation, a 30-minute fracturing episode near the pit crater (accompanied by tilt) marked the emplacement of magma. At 1604 an E-W fracture opened 200 m below the rim on the E flank producing only a small amount of lava. After 30 hours of tremor,

Piton de la Fournaise Volcano (continued)

seismic activity remained weak, similar to the September-October shallow fracturing.

From 2-6 December a shallow seismic crisis occurred in the summit area. At 0700 on 6 December, a fissure eruption accompanied by tremor began in the bottom of Dolomieu Crater. Two vents and a fissure were observed in the bottom of the crater. As of 15 December, the eruption continued as one vent emitted small quantities of lava and violent degassing events occurred from spatter cones. Intense seismicity was still being recorded at summit stations.

In June 1985 fissures formed on the central cone in the volcano's first eruption since early 1984. Three more lava-producing episodes occurred that year in August, September, and December. The 17 x 10^6 m^3 of December lava covered more than 95% of the crater floor. In March, lava emerged from fissures outside Enclos Caldera for the first time since 1977, and flowed into the sea. On 29 March a pit crater formed in the SE section of Dolomieu Crater. Lava from the December eruption emerged from one edge of the new pit crater and drained into the pit. Wall collapse and a brief eruption from the pit crater in July had been the last activity at the volcano.

Information Contacts: H. Delorme, B. Gillet, and J.C. Delmond, Observatoire Volcanologique du Piton de la Fournaise, 14 R.N. 3, 27 ème km, 97418 La Plaine des Cafres, Réunion Island; P. Bachelery, Laboratoire de Geologie, Université de la Réunion, B.P. 5, 97690 Sainte-Clothilde, Réunion Island; J.L. Le Mouel, J.L. Cheminee, A. Hirn, P.A. Blum, and J. Zlotnicki, Institut de Physique du Globe de Paris, Direction des Observatoires Volcanologiques, Tour 14, Université de Paris VI, Place Jussieu, 75230 Paris Cedex 05, France.

Etna Volcano, Sicily, Italy (37.73°N, 15.00°E). The following is a report from Romolo Romano.

"The eruption that began 30 October (see last month's Bulletin) was continuing in early December. As of 9 December, two eruptive vents were still active, together with a pit crater at around 2850 m altitude (figure 8) that generally showed strong gas emission but at times (15 November) violent expulsions of ash and/or sporadic ejection of incandescent material. A substantial spatter cone has formed at the eruptive vent at 2600 m altitude, from which strong gas emissions have occurred since mid-November. The main lava channel originates at the base of the cone, and since the end of November has been an essentially continuous lava tube (with at least seven 'windows' in its roof) down to 1900-2000 m altitude, where a few ephemeral effusive vents have formed. Several lava flows fanned out from these vents, rarely going below 1500 m and remaining within the Valle del Bove. The more active lava flows have generally moved east. On 19 November one of these reached 1325 m altitude, about 5 km from the vent.

"A large spatter cone (called Monte Rittmann in memory of our beloved teacher) formed around 2300-2350 m, and reached a height of about 100 m. From its base, a lava overflow started at the beginning of December and fed a flow that advanced about 700 m before stopping behind Monte Simone. Monte Rittman has shown almost continuous strombolian activity, more or less violent and often accompanied by strong explosions. Expulsions of ash have also been observed. The eruptive vents at lower elevation have not been active since 25 November. These vents, one exclusively explosive (at about 2250 m altitude) and two primarily effusive (2200 m and 2190 m altitude) were very active during the first weeks of the eruption, helping to form a large lava field. The flow fronts are generally wide (at times more than 100 m) and high (at times more than 10 m). An initial estimate, still to be confirmed, suggests

Etna Volcano (continued)

that the volume of lava is around 25 x 10^6 m^3. It is difficult at this time to evaluate the surface covered by the lava, but it should be more than 4 km^2.

"From the E vent of the central crater (the Chasm) more or less violent emissions of reddish ash have continued without interruption. Only emissions of gas and vapor were recorded from the other summit-area vents.

"Only a few weak earthquakes were recorded during November and the first few days of December. Volcanic tremor remained at high levels (5-10 times normal), with variations related to changes in the eruptive activity."

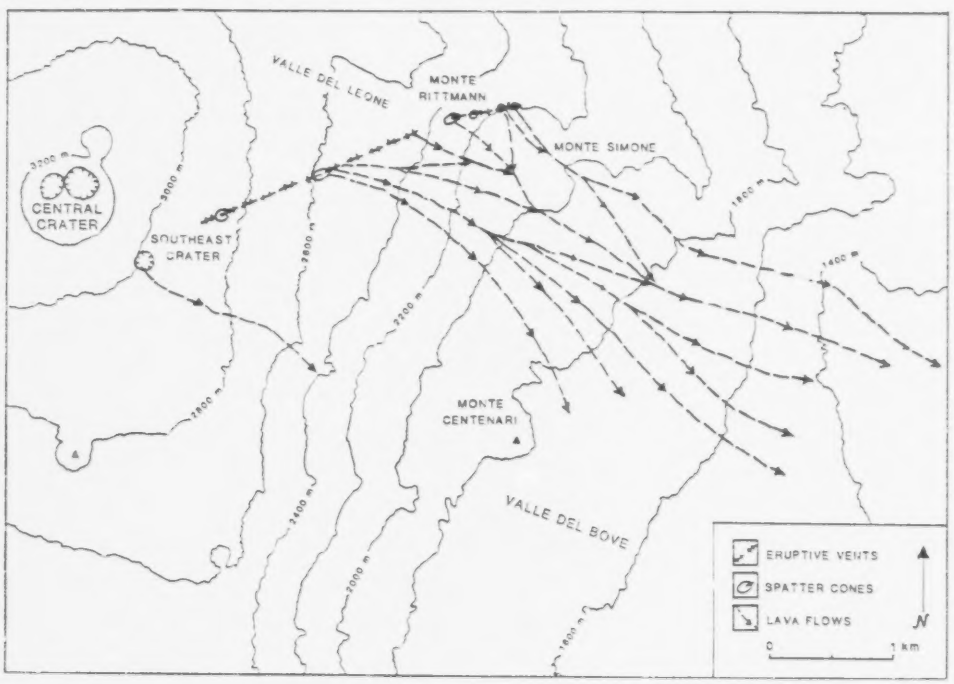

Figure 8: Sketch map of eastern summit area showing new fissures, lava flows, and spatter cones.

Information Contacts: R. Romano, T. Caltabiano, D. Condarelli, and O. Consoli, Istituto Internazionale di Vulcanologia, Viale Regina Margherita 6, 95123 Catania, Italy; S. Gresta, Istituto di Scienze della Terra, Università di Catania, Italy.

Ruiz Volcano, Colombia (4.88°N, 75.37°W). All times are local (= GMT - 5 hours). The following report from the Observatorio Vulcanológico Nacional summarizes activity from 11 November to 11 December.

"Activity remained at about the same level as for the last report (11 October - 11 November) but showed different character and location. Shallow (non-tectonic) seismic events, which increased at the end of October and early November, were more frequent than during any previous month in 1986. From measurements of station-to station amplitude ratios this high-frequency activity appeared to be west of the volcano. Low-frequency events during earlier months had been centered more to the east, suggesting a possible relationship with tectonic-type swarms in April and late October (see SEAN Bulletins v. 11, nos. 5 and 10). During the same time period, the

Ruiz Volcano (continued)

frequency of shallow (explosion-type) seismic events increased. Harmonic tremor remained at low levels with occasional increases correlating with increases in shallow seismic activity.

"The crater fumarole generally emitted very small steam plumes, bu some plumes reached more than 1 km when wind speeds were low. Hot springs 10 km NW of Arenas Crater showed a decrease in pH and an increase in temperature for the first time since the pre-eruption period of 1985. Ash emission was the lowest since 4 May, 1986. COSPEC measurements were infrequent due to poor weather conditions but average SO_2 emissions were between 2000 and 3000 metric tons per day. The latest measurement, on 10 December, was 1700 tons per day."

Information Contact: Hansjürgen Meyer, INGEOMINAS - Observatorio Vulcanológico de Colombia, Apartado Aereo 1296, Manizales, Colombia.

Masaya Volcano, W Nicaragua, (11.98°N, 86.15°W).

Intensive rock landslides began at midday on 12 November on the S and W sides of Santiago Crater. Part of the SW wall collapsed, extending Santiago into a section of Nindirí crater (figure 9). A floor collapse accompanied the slides. Two seismographs near the crater have recorded only seismicity produced by rockfalls down the 350 m crater wall.

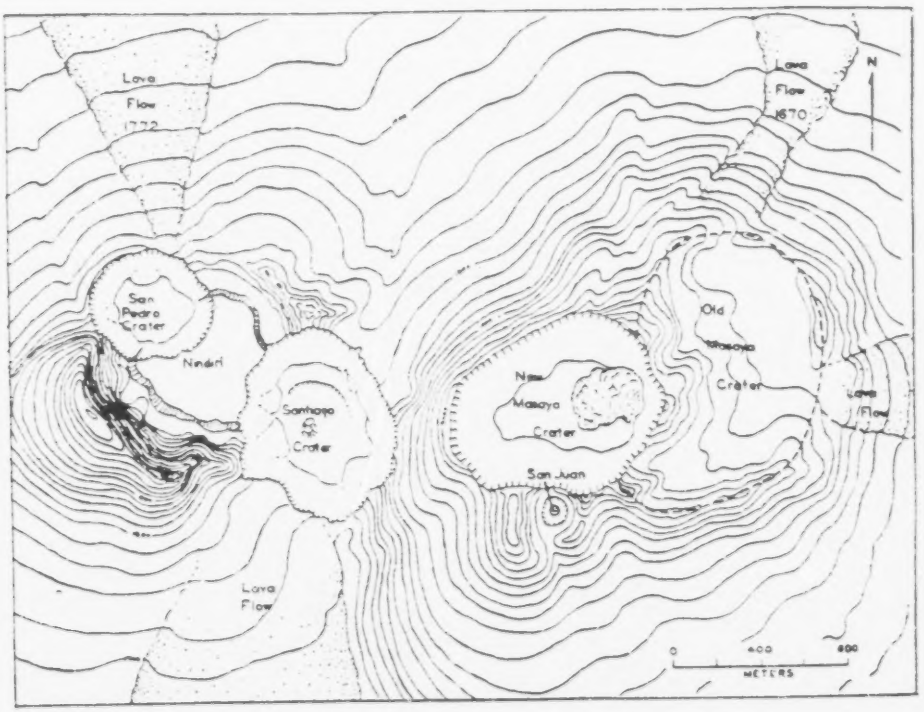

Figure 9: Map of Masaya from Mooser, F., Meyer-Abich, H., and McBirney, A., 1958, Catalogue of the Active Volcanoes of the World, Part VI.

Masaya Volcano (continued)

Reactivation of two faults or fissure systems facilitated continued wall collapse. One prominent fault cuts NE/SW through the crater and the other extends NW around the edge of the crater. A substantial decrease in fumarolic activity followed the collapse with only several small fumaroles remaining along the NE/SW fault in the crater bottom.

Guatemalan newspapers reported that the Civil Defense staff closed access to Masaya Volcano National Park on 20 November. A government communique stated that the rock slides closed a fissure (possibly the pit crater) that formerly emitted large plumes and lava.

Santiago crater is one of 4 low, shield-like collapse craters that lie near the center of Masaya Caldera. Santiago is the currently active crater and has had 5 recorded degassing episodes since its formation in 1850-1853. A frozen lava lake has filled the crater since 1965; lava was almost continuously visible in a hole within the lava lake until 1974. The most recent degassing began in 1979 and was continuing several years later (Stoiber and Williams, 1986; SEAN Bulletin v. 10, no. 11). Major eruptions have not accompanied the degassing or formation of the crater.

Reference: Stoiber, R.E. and Williams, S.N., 1986, Sulfur and Halogen Gases at Masaya Caldera Complex, Nicaragua: Total Flux and Variations with Time; Journal of Geophysical Research, Vol. 91, No. B12, p. 12,215-12,231.

Information Contacts: Douglas Fajardo and Petr Hradecky, Instituto Nicaraguense de Estudios Territoriales, Apartado Postal 1761, Managua, Nicaragua; Prensa Libre newspaper, Guatemala City, Guatemala.

Santiaguito Dome, W Guatemala (14.76°N, 91.55°W). All times are local (GMT - 6 hours)

A lateral blast and pyroclastic flow occurred on 1 December at 1330, damaging 2.5 km^2 of vegetation on the south flank. Ash clouds reached 3600 m height and up to 5 cm of ash were deposited. Three new fumaroles appeared on the south flank.

Newspapers reported that debris from the eruption blocked two rivers and caused floods in several villages. Many families were evacuated. Explosions, increased seismic activity, and continuing lava flow from the crater were reported on the day of the eruption.

Santiaguito is a dacite dome complex that has been growing on Santa Maria Volcano's SW flank since 1922. Rapid extrusion of lava occurred in the early 1970's when a long lava flow extended to the south and a pyroclastic flow emerged from the foot of the flow. Our most recent report of explosive activity and seismicity was in January and early February 1985 (see SEAN Bulletin v. 10, no. 2).

Information Contacts: Eddy Sánchez and Edgar Quévec, INSIVUMEH, 7a Avenida 14-57, Zona 13, Guatemala City, Guatemala; ACAN News, Panama City, Panama.

Pacaya Volcano, S Guatemala (14.38°N, 90.60°W).

Two cones have been growing within MacKenney Crater in October and November. On 18 and 23 November, explosions alternated at about 30-60-second intervals from the two cones, 3 and 5 m high and about 10 m apart. Ejecta from the new cones fell on the outer flanks of MacKenney Cone on 23 November. Narrow lava flows on the W flank of

Pacaya Volcano (continued)

MacKenney Cone were observed on 16 November. The highest vent feeding the flows was about 300 m below the summit. Lava extended as much as 500 vertical meters downslope.

Pacaya began to erupt in March 1983. Activity from various vents has built new cones within and near MacKenney Crater, and fed numerous lava flows.

Information Contacts: Alfredo MacKenney, 2a Avenida 10-60, Zona 1, Guatemala City, Guatemala; R. Stoiber, R. Pool, D. Barnett, and other geologists, Department of Earth Sciences, Dartmouth College, Hanover, New Hampshire 03755 USA.

Parícutin Volcano, W Mexico (19.48°N, 102.25°W).

When geologists visited Parícutin 26 November, fumaroles were emitting HCl-dominated gases. The temperature of Ahuan fumarole (on the SW flank) was 375°C, about 100° lower than in November 1985. Other fumaroles remained at about 100°C. No other changes were observed. Parícutin has remained quiet since it was built in a 9-year eruption that began in 1943.

Information Contacts: Richard Stoiber, Charles Connor, and other geologists, Department of Earth Sciences, Dartmouth College, Hanover, New Hampshire 03755 USA.

Colima Volcano, SW México (19.42°N, 103.72°W).

On 29 November, geologists observed the volcano from Nevado del Colima, an eroded cone 5 km to the N. A very small plume was emerging from the summit. COSPEC measurements suggested that SO_2 was being emitted at a rate of perhaps 8 metric tons per day.

No eruptive activity at Colima has been reported since residents of nearby towns observed an ash plume and incandescent tephra in early January. Geologists who climbed the volcano in February saw vigorous fumarolic activity, and rockfalls from the lava dome that suggested its continuing growth (see SEAN Bulletin v. 11, no. 3).

Information Contacts: Same as for Parícutin.

Mt. St. Helens Volcano, Cascade Range, S Washington, USA (46.20°N, 122.18°W).

Since the dome-building activity in late October, the volcano has remained quiet. From November through early December, seismicity and SO_2 emissions were at background levels. SO_2 could only be measured on 3 days: 3 November, 60±20 metric tons per day (mtpd); 2 December, 33±5 mtpd; and 9 December, 80±15 mtpd. No significant deformation was recorded.

Information Contacts: Donald Swanson, and Jeff Sutton, USGS Cascades Volcano Observatory, 5400 MacArthur Blvd., Vancouver, Washington 98661 USA; Chris Jonientz-Trisler, Geophysics Program, University of Washington, Seattle, Washington 98195 USA.

Pavlof Volcano, Alaska Peninsula, Alaska, USA (55.42°N, 161.90°W). All times are local (= GMT - 9 hours).

The eruption that began in early November (see last month's Bulletin) continued into December with steam plumes from the N-summit vent and ash emissions from a SE flank vent 200-300 m below the summit (table 2). Steam and ash emissions were continuing at 1840 on 10 December when pilots saw an orange-red glow in a cloud above

Pavlof Volcano (continued)

the summit. They did not observe any material moving through the clouds. The next day at 1324, airplane pilots reported that 3-4 lava flows had moved down the SSE flank and that one had reached the Pacific Ocean at Pavlof Bay, 10 km from the summit; a 300 m-high steam column rose where the flow entered the water.

Seismicity in early November reached more than 150 events a day, all apparently explosion shocks. Individual events had similar durations but variable amplitudes. Only a few hours of tremor were recorded.

Date	Time	Observers	Activity
17 Nov	1006-1600	CB,EL,JC MA	constant steaming from N vent; black ash pulsed (every 5-8 minutes at 1200) from SE vent, feeding a plume to 3600-4200 m altitude that drifted 25-30 km S; ash covered the entire SE flank
18 Nov	1200-1652	JC,JF,CB	steam emission from N vent; ash emission from SE vent, drifting SW
19 Nov	1030	EL	ash plumes to 3000-3300 m altitude emitted at 5-minute intervals from SE vent
19 Nov	1600	RA	no eruption apparent despite clear visibility
21 Nov	1522	PA	small amounts of ash formed 1.5 km-long plume
23 Nov	1545	Cessna	plume rose to 3000 m altitude; drifted NE
26 Nov	1130	LG,DM	dark gray ash plume rose 90-150 m above summit from SE vent and drifted 8 km SE
2 Dec	1045	MB	ash column from SE vent rose to 3000 m, drifted E
2 Dec	1359	JC,MB	60 m-high brown ash cloud from SE vent
10 Dec	1840	LG,DM	Pilots at 3600 m elevation observed an orange-red glow in a thin cloud horizon at 2500 m altitude (just above summit); see above
11 Dec	1324	HB,DM	SE vent ash plume reached 4500-5400 m altitude and drifted WSW for 32 km; 3-4 narrow lava flows had moved down the SSE flank; see above
16 Dec	1140	LG	60 m-high steam plume from the SE vent; no other activity was observed

Table 2: Summary of reports collected by John Reeder. Observers: Edward Livingston, Lee Goch, James Fredenhagen, Don Munson, and Harold Black (Reeve Aleutian Airways); Clayton Brown (Alaska State Fish and Game); Jerry Chisum (MarkAir); Marsha Brown (Federal Aviation Administration, Cold Bay); un-named observers from Reeve Aleutian Airways (RA), MarkAir (MA), Peninsula Airways (PA), and a private plane (Cessna).

Correction:

In last month's report on Pavlof, gray-black ash was reported to have covered the SE flank of Pavlof on 14 November. The actual observation date was 13 November.

Information Contacts: John Reeder, Alaska Division of Geological and Geophysical Surveys, P.O. Box 772116, Eagle River, AK 99577 USA; John Taber, Lamont-Doherty Geological Observatory, Palisades, NY 10964 USA.

Atmospheric Effects

Lidar stations continued to detect increased stratospheric aerosols in November (table 3). At Mauna Loa, Hawaii (19.5°N, 155.6°W), a substantial increase in both peak and total backscatter was measured 18 November (figure 10) and numerous tiny sharp peaks were evident on initial data. From Fukuoka, Japan (33.65°N, 130.35°E),

Atmospheric Effects (continued)

very sharp peaks were recorded between 20.5 and 22 km altitude on 10, 17, and 21 November. Lidar at Hampton, Virginia (37.1°N, 76.3°W) detected both increased total backscatter and the presence of new higher-latitude layers in late November and early December. A thin layer at 21 km altitude was measured from Garmisch-Partenkirchen, Germany (47.5°N, 11.0°E) on 7 November, slightly higher than another new layer that had been observed on 24 October (see last month's Bulletin).

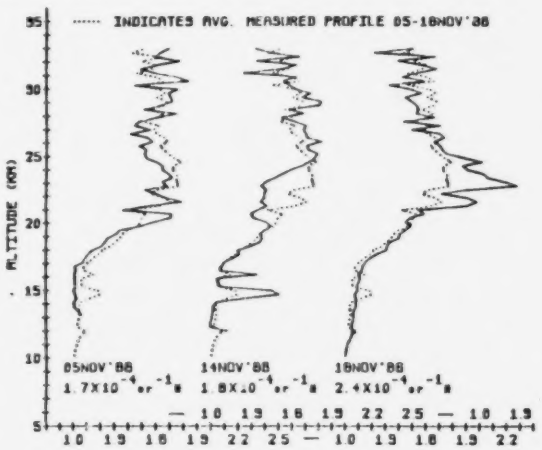

Figure 10: Lidar profiles from Mauna Loa, Hawaii, 5-18 November. The dotted line superimposed on each profile represents the average November data.

No eruption columns are known to have penetrated the stratosphere since the November 1985 eruption of Ruiz, although a brief strong explosive eruption occurred at Etna on 24 September, shortly before the initial appearance of increased aerosols. M. P. McCormick suggested the following interpretation for the observations.

"At certain times of the year, SAGE and SAGE II satellite observations show layers at altitudes well above the 'normal' stratospheric aerosol peak for that particular latitude. A clear seasonal cycle has become evident in both hemispheres, showing low-latitude type layers outside the equatorial belt in late fall and winter periods, with very few cases observed in summer (figure 11). The most obvious explanation for this 'extra' layer is that we are observing transport of low-latitude aerosols into the winter hemisphere by planetary wave activity, which is greater in the winter hemisphere. Care must be given, therefore, to interpreting local measurements by lidar or made in situ which show this type of layer as possibly due to a 'new' volcanic eruption."

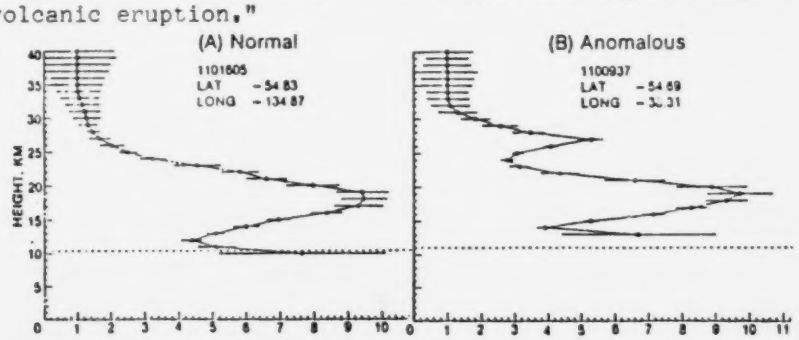

Figure 11: Extinction ratio (aerosol plus molecular extinction divided by molecular extinction) plotted as a function of altitude for two SAGE II observations taken on the same day at different longitudes. The B profile shows a secondary peak at about 27 km, well above the 'normal' peak for this latitude. Presented by G. S. Kent at the Sixth Conference on Atmospheric Radiation, Williamsburg, VA, May 12-16, 1986.

Atmospheric Effects (continued)

TABLE 3

LOCATION	DATE	LAYER ALTITUDE IN KM (peak in parentheses)		BACKSCATTERING COEFFICIENT	RATIO	INTEGRATED
Mauna Loa, Hawaii	5 Nov	17-25	(20.4)	0.28×10^{-7}	1.7	0.17×10^{-3}
(19.5°N, 155.6°W)			(21.6)	0.17×10^{-7}	1.8	
	14 Nov		(14.7)	0.54×10^{-7}	1.5	0.18×10^{-3}
			(16.2)	0.30×10^{-7}	1.4	
			(19.8)	0.20×10^{-7}	1.4	
			(26.1)	0.12×10^{-7}	1.8	
	18 Nov	15-25	(22.8)	0.33×10^{-7}	2.3	0.24×10^{-3}
Fukuoka, Japan	8 Nov	14.7-23.5	(19.1)		2.47	
(33.65°N, 130.35°E)	10 Nov	16.0-23.5	(19.1)		2.27	
			(22.1)*		2.83	
	17 Nov	16.5-22.5	(19.9)		2.56	
			(21.4)*		3.05	
	19 Nov	17.0-22.5	(19.9)		2.87	
	21 Nov	17.5-22.0	(20.6)*		3.46	
	26 Nov	17.0-23.0	(19.9)		2.47	
			(22.1)		2.61	
Hampton, Virginia	19 Nov	12-29				0.22×10^{-3}
(37.1°N, 76.3°W)		12-23	(19.5)		1.43	
		23-29	(24.3)		1.71	
	20 Nov	11.9-29				0.18×10^{-3}
		11.9-22	(19.5)		1.42	
		22-26	(23.2)		1.39	
		26-29	(26.8)		1.35	
	3 Dec	9.8-29				0.21×10^{-3}
		9.8-23.5	(19.7)		1.47	
		23.5-29	(26.0)		1.40	
	4 Dec	10.5-29	(19.1)		1.40	0.16×10^{-3}
Garmisch-Partenkirchen	7 Nov	13-31	(18.6)		1.4	
West Germany			(21.0)		1.5	
(47.5°N, 11.0°E)	24 Nov	11-28	(17.4)		1.4	

Table 3: Lidar data from various locations, showing altitudes of aerosol layers. Note that some layers have multiple peaks. Backscattering ratios from Fukuoka, Japan are for the Nd-YAG wavelength of 1.06 microns; all others are for the ruby wavelength of 0.69 microns. An explanation of the relationship of ruby and Nd-YAG values is on p. 15-16 of SEAN Bulletin v. 9, no. 10. Integrated values show total backscatter, expressed in steradians^{-1}, integrated over 300-m intervals from 16-33 km at Mauna Loa and from the tropopause to 30 km at Hampton. Altitudes of maximum backscattering ratios and coefficients are shown for each layer at Mauna Loa. Layers from Fukuoka, Japan marked * have very sharp peaks.

Information Contacts: M. P. McCormick and William Fuller, NASA Langley Research Center, Hampton, Virginia 23665 USA; Thomas DeFoor, Mauna Loa Observatory, P. O. Box 275, Hilo, Hawaii 96720 USA; Motowo Fujiwara, Physics Department, Kyushu University, Fukuoka 812, Japan; H. Jaeger, Fraunhofer-Institut fur Atmospharische Umweltforschung, Kreuzeckbahnstrasse 19, D-8100 Garmisch-Partenkirchen, West Germany.

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EARTHQUAKES

DATE	TIME (GMT)	MAGNITUDE	LAT.	LONG.	DEPTH OF FOCUS	REGION
14 November	2120	7.8 M_S	24.10°N	121.83°E	shallow	Taiwan
14 November	2304	6.3 M_S	23.88°N	121.82°E	shallow	Taiwan
25 November	1355	5.5 M_S	44.14°W	16.41°E	shallow	Yugoslavia
30 November	0520	5.0 m_b	5.46°S	35.83°W	shallow	Brazil

Fourteen people were killed and at least 45 were injured from 2 strong earthquakes that were centered off the E coast of Taiwan. One man was missing when 11 fishing boats capsized. More than 60 houses were destroyed, 24 in the village of Ilan, and many buildings collapsed. One office building was left tilted at a 15° angle. Rockslides injured 6 and killed one in Hualien. It was felt in Okinawa and in Japan.

Minor injuries were sustained by 14 people during the earthquake in central and western Yugoslavia. Many houses and buildings, including a new hospital, were damaged in the Knin-Grahavo area and in Bosnia. Landslides and falling rocks blocked 2 railroad lines. It was felt as far away as Venice, Naples, the southeastern Italian peninsula, and SE Austria.

More than 1500 houses were reported damaged or destroyed in the Natal-Joao Camara area of Rio Grande do Norte state of northeastern Brazil by the strongest in a series of more than 4,000 earthquakes that began in August. An undetermined number of people were injured, and about 5,000 people have fled the area.

FIREBALLS

Arabian Sea, 9 November 1955 GMT
Observers: Flight Officers of Qantas flight QF 015 (Singapore-Athens)
Location: 21.07°N, 62.08°E, aircraft course 292° magnetic, alt. 10.6 km
1st Sighting: Azim. 312°, alt. 40°
Last sighting: Azim. 342°, alt. 5°
Duration: 1.5 seconds
Magnitude: (none given)
Color: White, then red and blue
Trail: 2 second afterglow

NW of Australia, 7 November 1552 GMT
Observer: Cpt. Wastell of Qantas flight QF 30 (Den Pasar/Bali-Melbourne)
Location: 15.00°S, 121.25°E, aircraft course 135° true, alt. 11.2 km
1st Sighting: Azim. 130°, alt. 15°
Last sighting: Azim. 140°, alt. 15°
Duration: 2 seconds
Magnitude: 3 X brighter than Venus
Color: White

Information contact: Gerhard Polnitzky, Universitaets-Sternwarte, Tuerkenschanzstrasse 17, A-1180 Vienna, Austria.

England, 28 September 1918 GMT in Castleford, 1917 GMT in Rayleigh
Two people observed fireballs in southern and north-central locations.

Observer: Gordon Ward
Location: Castleford, W. Yorkshire (53.72°N, 1.33°W)
1st Sighting: R.A. $0^h\ 0^m$, alt.24°
Last sighting: R.A. $22^h\ 15^m$, alt.-6°
Duration: 2 seconds
Magnitude: -14

Observer: Philip R. Benson
Location: Rayleigh, Sussex (51.08°N, 0.12°E)
1st Sighting: R.A. $5^h\ 20^m$, alt.60°
Last sighting: R.A. $7^h\ 30^m$, alt.55°
Duration: 5 seconds
Magnitude: -10 ?

Fireballs (continued)

Color: White-blue
Trail: Varied in brightness

Color: White
Trail: Distorted to 'N' shape

Information contact: Robert A. MacKenzie, British Meteor Society, 26, Adrian Street, Dover, Kent, CT17 9AT England.

West Germany, 1 August 2150 GMT

"A fast-moving fireball of -14 maximum absolute magnitude was photographed by 4 Czech stations of the European network. The fireball travelled an 84-km luminous trajectory in 2.4 seconds. The following results are based on all available photographs measured by J. Bocek."

		Beginning	Maximum Light	Terminal
Velocity	km/s	42.9	41.5	38.8
Height	km	93.56	75.4	61.7
Latitude	°N	50.28	50.52	50.70
Longitude	°W	11.74	11.25	10.86
Absolute Magnitude		-6.09	-14.0	-5.9
Photomet. mass/kg		37.	30.	None
Z R	degrees	67.54	-	68.23

Fireball Type: IIIA

Radiant (1950.0)		Observed	Geocentric	Heliocentric
Alpha	degrees	336.63	337.05	-
Delta	degrees	-3.73	-4.91	-
Lambda	degrees	-	-	293.5
Beta	degrees	-	-	4.74
Initial Velocity	km/s	42.9	41.2	37.9

Orbit (1950.0)

A	2.9	A.U.	Alphelion	5.7	A.U.	Ascending Node	128.842°
E	0.978		Omega	333.4°		Inclination	17.4°
Q	0.064	A.U.					

Information contacts: Zdenek Ceplecha and Pavel Spurny, Ondrejov Observatory, 251 65 Ondrejov, Czechoslovakia.

Bay of Bengal, 6 November 1655 GMT
Observer: F/O Alford, S/O Johnson of Qantas flight QF1,001-064
Location: 8.78°N, 88.80°E, aircraft course 300° magnetic, alt. 9.4 km
1st Sighting: Azim. 210°, alt. 20°
Last sighting: Azim. 210°, alt. 10°
Duration: 2 seconds
Magnitude: Dazzling
Color: White
Trail: Luminous, 3 second afterglow
Termination: Flared, disappeared above horizon

Information contact: Same as for Australia.

Florida USA, 28 November 0302 GMT (27 November 2202 Eastern Standard Time)
Observers: Martha Bisplinghoff
Location: SE Orange Co.(28.5°N, 81.1°W)
1st Sighting: Azim. 100°, alt. 45°
Last sighting: Azim. 160°, alt. 10°
Duration: 3 seconds
Magnitude: Brighter than full moon
Color: White, changed to blue-green
Trail: 5°-8° long luminous blue-green
Termination: Flared brightly, passed behind trees
Sound: Sizzling noise while in sight

Information contact: W. Blankenbeckler, John Young Planetarium, 810 E. Rollins St. Orlando, FL 32803

Fireballs (continued)

Georgia USA, 10 November 2338 GMT, (1838 Eastern Standard Time)
Two people observed a fireball in separate locations in central Georgia.

Observer: Bunny Pritchett
Location: Gray, Jones County (33.01°N, 83.55°W)
Path: NW to W
Duration: 4 seconds
Apparent Velocity: Slow
Magnitude: Much brighter than Venus
Size: Smaller than moon
Termination: Disappeared behind trees

Observer: Mike Jones
Location: S of High Falls, Monroe County (33.10°N, 84.00°W)
Path: Azim. 270°, alt. 30° to 5°
Duration: 2 seconds
Apparent velocity: Slow
Magnitude: Bright as cresent moon
Size: Larger than a star
Termination: Disappeared behind trees

Information contact: William Peck, Mark Smith Planetarium, Macon GA 31210 USA.

Illinois USA, 19 November 0205 GMT (18 November, 2005 Central Standard Time)
Observer: Richard Svehla
Location: Waukegan (42.35°N, 87.88°W)
Path: NNW to NW, downward at 30° angle
Duration: 2 seconds
Apparent velocity: Slow
Magnitude: Brighter than quarter moon
Size: Much larger than Venus
Color: Green then reddish
Trail: Luminous
Termination: Vanished above horizon

Information contact: Richard Svehla, 971 N. Estes, Gurnee, IL 60031.

Massachusetts USA 28 November 2230 GMT (1730 Eastern Standard Time)
Observer: Blanche Farrell
Location: Jefferson (42.62°N, 71.88°W)
Path: Moved NNW from zenith
Duration: 5 seconds
Apparent velocity: Slow
Magnitude: -8
Shape: Round with small tail
Color: Bluish green
Trail: Tail got longer as it descended
Termination: Disappeared above horizon

Information contact: Jean Ingraham, New England Science Museum, 222 Harrington Way, Worcester, MA 01604.

Minnesota USA, 5 November 0056 GMT (4 November 1856 Central Standard Time
Observer: Jim Bedient
Location: Hastings (44.67°N, 92.86°W)
1st Sighting: Azim. 005°, alt. 40°
Last sighting: Azim. 345°, alt. 12°
Duration: 4 seconds
Apparent Velocity: Slow
Magnitude: -6, brighter than Venus
Color: Green-white
Trail: Luminous white
Termination: More than 6 red fragments

Information contact: Jim Bedient, 816 S. Water St., Northfield, MN 55057.

Missouri USA, 21 October 2333 GMT (1833 Central Daylight Time)
Observer: Greg Jarboe
Location: Doniphan (36.65°N, 90.76°W)
1st Sighting: Azim. 295°, alt. 30°
Last sighting: Azim. 280°, alt. 20°
Duration: 1-2 seconds
Apparent velocity: Fast
Magnitude: -8
Color: Green-blue
Termination: Fragmented last 1/3 of path

Information contact: Greg Jarboe, RR 3 Box 131M, Doniphan, MO 63935.

New Jersey USA, 22 November 0330 GMT (21 November 2230 Eastern Standard Time)
Observer: E. J. Noga, Jr.
Location: Sicklerville (39.71°N, 74.96°W)
Path: ESE, straight down from 60° alt.

Pennsylvania USA, 29 October 0443 GMT (28 October 2343 Eastern Standard Time)
Observer: Robert R. Young
Location: Harrisburg (40.15°N, 76.88°W)
Path: NE to SE, 70° alt. ended in Gemini

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Fireballs (continued)

Duration: About 5 seconds
Apparent Velocity: Slow
Magnitude: Almost as bright as full moon
Color: Silvery-white
Trail: Short tail, sparks
Termination: At 45° fragmented into 5-6 pieces, vanished above horizon

Information contact: E. J. Noga, Jr. 203 Foster Ave., Sharon Hill, PA 19079.

West Virginia USA, 28 November 1040 GMT (0540 Eastern Standard Time)
Observer: Daryl Bailey
Location: Big Tyler Mt. (38.33°N, 81.63°W)
1st Sighting: Azim. 330°, alt. 60°
Last sighting: Azim. 320°, alt. 0
Duration: 2 seconds
Apparent Velocity: Fast
Magnitude: Brighter than full moon
Color: Bluish-white
Shape: Slim teardrop
Termination: Fragmented, dropped below horizon while still bright

Information contact: Greg Rawlings, Director, Sunrise Planetarium, 746 Myrtle Rd. Charleston, WV 25314.

Duration: 3 seconds
Apparent velocity: Slow
Magnitude: -8, brighter than Venus
Color: Greenish-white
Trail: 8° long, luminous green, lasted 5-10 seconds
Termination: 4-5 fragments vanished above horizon
Information contact: R. R. Young, 329 S. Front St., Harrisburg, PA 17104.

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